JYU DISSERTATIONS 574

Priyanka Patel

Evaluating a Computer-Assisted Phonics Intervention for Improving Foundational English Literacy Learning in Multilingual India

UNIVERSITY OF JYVÄSKYLÄ
FACULTY OF EDUCATION AND PSYCHOLOGY

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Esitetään Jyväskylän yliopiston kasvatustieteiden ja psykologian tiedekunnan suostumuksella
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ABSTRACT

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The overall aim of this dissertation was to examine whether GraphoLearn English Rime, a computer-assisted phonics-based intervention, could effectively support children's foundational English literacy learning in India. Through a series of three studies, this research evaluates whether GraphoLearn would lead to significant improvements in children's foundational English literacy skills (Studies I and II), as well as examines the relationship between children's first (Hindi) and second (English) language literacy skills (Study III) to better inform English literacy instruction and intervention. Both Studies I and II employed a randomized controlled trial design to evaluate the efficacy of GraphoLearn English Rime with children across Grades 1-3 in English-medium government schools. Children in the intervention group played GraphoLearn and children in the control group played a math game. Both groups of children played their respective games during school hours through touchscreen devices equipped with headphones. The children were pre- and post-tested on a set of in-game and out-of-game oral and paper-based measures designed to assess basic skills of foundational literacy. In Study II, children were also assessed at pre-test using a set of oral and paper-based Hindi measures, which for a majority of children was their first language. The data collected through the oral and paper-based English and Hindi measures were used in Study III to examine the phonological predictors of children's literacy skills within and across the two languages. Overall, results indicated the efficacy of GraphoLearn in improving subskills of reading, specifically children's knowledge of grapheme-phoneme correspondences. However, the results also highlighted the limitations of computer-assisted interventions when used in the absence of comprehensive literacy instruction and teacher support. Examination of the phonological predictors of children's L1 and L2 literacy skills reaffirmed the importance of English phonemic awareness for English decoding. There was also evidence indicating cross-language contributions of Hindi phonological awareness to English decoding. Taken together, there is strong evidence indicating that children attending English-medium schools in India can benefit from phonics-based literacy instruction but there remains a need to understand how technologies like GraphoLearn utilized for learning in such contexts.

Keywords: GraphoLearn, English learners, foundational literacy, phonics, India, cross-language transfer, phonological awareness, ed-tech, intervention

TIIVISTELMÄ (ABSTRACT IN FINNISH)

Patel, Priyanka
Lukemaan oppimisen tukemiseen kehitetyn tietokoneavusteisen intervention arviointitutkimus monikielisessä Intiassa
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Tämän väitöskirjan tavoitteena oli tutkia, voisiko GraphoLearn English Rime, tietokoneavusteinen fonologisen ja ortografisen tiedon yhdistämiseen kehitetty lukutaitointerventio, tehokkaasti tukea lasten englannin lukutaidon oppimista monikielisessä Intiassa. Osatutkimusten avulla arvioitiin, parantaisiko GraphoLearn merkittävästi lasten englannin kielen lukutaitoa (tutkimukset I ja II). Lisäksi tutkitaan lasten ensimmäisen (LI, hindi) ja toisen (L2, englannin) kielen lukutaidon välistä suhdetta (Tutkimus III). Tutkimuksissa I ja II käytettiin satunnaistettua kontrolloitua tutkimusasetelmaa GraphoLearn English Rimen tehokkuuden arvioimiseksi luokkien 1–3 lapsilla. Lapset kävivät englanninkielisiä valtion kouluja kahdessa eri osassa Intiaa. Interventioryhmän lapset pelasivat GraphoLearnia ja kontrolliryhmän lapset matemaattista peliä. Molemmat lapsiryhmät pelasivat kouluaikana kuulokkeilla varustetuilla kosketusnäytöllisillä laitteilla. Lasten lukutaitoa ja lukutaitoon liittyviä kognitiivisia taitoja arvioitiin ennen interventiota ja intervention jälkeen sekä pelin sisäisillä että pelin ulkopuolisilla tehtävillä. Tutkimuksessa II lasten taitoja arvioitiin esitestissä käyttämällä englanninkielisten tehtävien lisäksi hindinkielisiä tehtäviä. Hindi oli suurimmalle osalle lapsista heidän äidinkielensä. Englannin- ja hindinkielisillä tehtävillä kerättyä aineistoa käytettiin myös tutkimuksessa III, jossa tutkittiin miten lasten fonologiset taidot eri kielissä ennustavat lukutaidon kehitystä näiden kahden kielen sisällä ja niiden välillä. Kaiken kaikkiaan tulokset osoittivat GraphoLearnin parantavan erityisesti lasten tietämystä grafeemien ja foneemien vastaavuuksista. Tulokset korostivat kuitenkin myös tietokoneavusteisten interventioiden rajoituksia, jos niitä käytetään ilman vastaavaa lukutaidon opetusta ja opettajan kattavaa tukea. Lasten L1- ja L2-lukutaidon fonologisten ennustajien tutkiminen vahvisti englanninkielisen foneemisen merkityksen englannin dekoodauksessa. Tulokset osoittivat myös, että hindin kielen fonologinen tietoisuus vaikutti englannin kielen lukemaan oppimiseen. Tulosten perusteella fonologisten taitojen ja foneemi-grafeemi-vastaavuuden tukeminen sekä äidinkielessä, että englannin kielessä on tärkeää. On kuitenkin edelleen tarpeen tutkia tietokoneavusteisia interventioita, jotta voidaan ymmärtää paremmin, kuinka GraphoLearnin kaltaisia sovelluksia hyödynnettäisiin parhaalla mahdollisella tavalla osana opetusta Intian monikielisessä koulukontekstissa.

Keywords: englanninkielen oppijat peruslukutaito, Intia, fonologinen tietoisuus, tietokoneavusteinen lukemaan oppiminen, interventio

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LIST OF ORIGINAL PUBLICATIONS

The dissertation is based on the following original publications:

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II. Patel, P., Torppa, M., Aro, M., Richardson, U., & Lyytinen, H. (2021). Assessing the effectiveness of a game-based phonics intervention for 1st and 2nd grade English language learners in India: A randomized controlled trial. *Journal of Computer Assisted Learning, 38*, 76-89. https://doi.org/10.1111/jcal.12592

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The author of the dissertation, considering the comments and suggestions of the co-authors, contributed to the collection of the data used in the studies, the statistical analyses, and the writing and reviews of the manuscripts listed above.

FIGURES

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1 INTRODUCTION

Despite the many advances of the 21st century, the world remains in the midst of a global learning crisis. To call even greater urgency to the matter, the World Bank introduced the concept of “learning poverty”, defined as the inability to read and comprehend a simple text by the age of 10 (World Bank Group, 2019a). It is estimated that 53% of children in low- and middle-income countries are learning poor. At the current rate of progress, this number is expected to only see a 10% decrease by 2030. A major driver of sustainable development and poverty reduction, literacy enables individuals to be active and productive members of society. It is estimated that the current rate of illiteracy is costing the global economy over $1 trillion US dollars annually (World Literacy Foundation, 2018). It is evident that having millions of children failing to acquire basic literacy is not just a threat to the prosperity of individual societies, but to the world as a whole.

India, which houses one of the world’s largest educational systems, is also home to a late-primary age population which is 55% learning poor (World Bank Group, 2019b). Deficient home learning environments, inadequate school readiness, rote methods of instruction, poorly trained teachers, over-ambitious curricular expectations, and a lack of early identification and remediation have been identified as some of the contributors to learning poverty in India (Banerji, 2018). In a country that offers primary education to over 250 million students in 31 mediums of instruction, solving the learning crisis is no small feat (Meganathan, 2011).

English, viewed as a language of opportunity, continues to play an ever-increasing role in the Indian education system. Parents ambitiously enroll their children into English-medium schools in hopes of a better future. Governments are responding to the demands by opening more English-medium schools and offering English instruction as early as Grade 1. As of 2019, it was estimated that over a quarter of school-going children in India are attending English-medium schools (Nagarajan, 2021). However, as is the case in many regional-medium schools, children are failing to learn. In 2016, a nationwide survey indicated that only 32% of Grade 3 children were able to read simple three-letter words in English (ASER Centre, 2016).

There is currently a sparse research-base around effective interventions to support the literacy development of children attending English-medium schools in India. This dissertation aims to contribute towards filling that gap by examining the efficacy of GraphoLearn English Rime, a computer-assisted phonics-based intervention for supporting foundational English literacy learning. This dissertation also examines the relationship between children's first (L1) and second (L2) language and literacy skills. The ultimate goal of this work is to develop an understanding of English literacy learning among children in India and explore the possibility of educational technology (ed-tech) to take a step towards the reduction of learning poverty.

1.1 India's Learning Crisis

In 2010, the passage of the Right to Education Act (RTE) made education free and compulsory for children ages 6-14 under the Indian Constitution. While school enrollment has consistently been over 95% even before the RTE went into effect, the act was successful in increasing enrollment among subgroups of children who were consistently out-of-school such as girls and children in the 11-14 age range (Wadhwa, 2018). Although India has made consistent progress in ensuring that children are enrolled in school, ensuring that children are learning has been much less consistent.

Prior to the passage of the RTE, 53% of children in Grade 5 were able to read a Grade 2 level text (see Figure 1); this is still nearly three years behind the grade level expectation. By 2012, that number saw a decline of over 10%. Much of this decline was attributed to previously out-of-school children who were now enrolling but starting out much further behind their consistently enrolled peers (Wadhwa, 2018). Students would be expected to eventually catch up, yet progress has been slow.

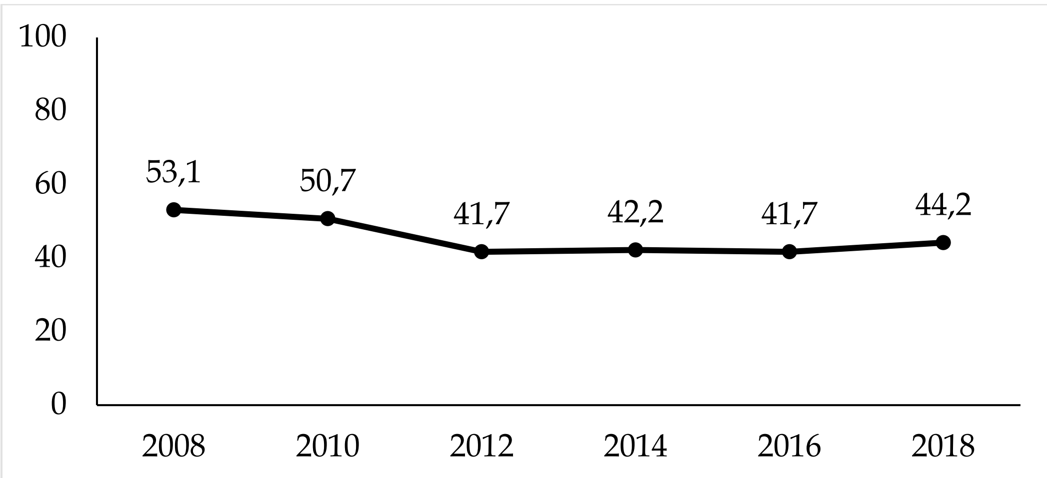

Figure 1 Percentage of Grade 5 children who were able to read a Grade 2 level text from 2008 to 2018 (ASER Centre, 2018)

Of significant concern is the finding that every year, a greater number of children are getting stuck at earlier stages of skill building (ASER, 2018). In 2010 it was seen that 17% of Grade 3 students were reading at "grade level" (i.e., they were able to read a Grade 2 text). However, 6.5% of Grade 3 students were unable to identify a single letter. By 2018, 21% of Grade 3 students were able to read at grade level, an improvement of four percentage points. But 16% of students failed to identify a single letter; a decline of nearly 10%. It is hard to deny that such trends are extremely concerning.

1.2 Multilingualism in India

India's highly multilingual landscape adds an additional layer of complexity, specifically to literacy learning in India. The Constitution of India recognizes a total of 22 languages which are spoken by over 96% of the population as a mother tongue. However, as of 2011, there were 270 languages reported with over 10,000 speakers (Census of India, 2011b). Hindi is recognized as the official language of the Union, and English, introduced in India by the British in the 17th century, is considered an associate official language (Graddol, 2010). Just over a quarter of the population identifies as bilingual and 7% identifies as trilingual (Census of India, 2011a). It is very common for individuals to use multiple languages in everyday life, with one language used in the workplace, a different language used with members of the local community, and the mother tongue used at home with family.

India's language in education policy, the three-language formula, is reflective of the great degree of multilingualism across the country. According to the three-language formula, children are required to learn to read in three languages upon the completion of secondary school (Joshi et al., 2017). Typically, two of these languages are Hindi and English with the third being the state/regional language. The three-language formula has been a part of the National Education Policy since 1968 and continues as the recommendation in the most recent version of the National Education Policy. One notable update, however, is that states, regions, and students have been given greater freedom to choose the languages learned so long as at least two of the three are native to India (Ministry of Human Resource Development, 2020). Across the 35 states in the country, 31 individual languages are offered as mediums of instruction in school. The second language is offered anytime between Grades 1 and 5, and the third language is offered anytime between Grades 3 and 9 (Meganathan, 2011).

English, once viewed as a language of the elite, holds increasing importance in the lives of all Indians (Graddol, 2010). A 2009 survey indicated that while 82% of Indians feel that knowing the state/regional language is important, 87% also believe that knowledge of English is important for life success (Graddol, 2010). There is no denying that English is a critical skill for upward mobility in India. English is the main language of instruction used in higher education across the country (Trines, 2018), thus being a necessary skill for postsecondary access.

Moreover, hourly wages in India have been found to be 13% higher for men who even speak some degree of English and 34% among fluent speakers as compared to those who speak no English (Azam et al., 2013). It is perhaps no surprise then that an increasingly large demand for English comes from those in the lower strata of society; English is seen as a vehicle for a better life. In a response to demand, schools across India are increasingly offering English as a medium of instruction. In 1993, only five percent of schools offered English as a medium of instruction at the primary level. By 2009, this had already more than tripled to over 15% (National Council of Education Research and Training, 2016).

1.3 English Literacy Instruction in India

The English-teaching scenario in India has been categorized in terms of teachers' English language proficiency and students' exposure to English outside of school (Nag-Arulmani, 2000). Based on this categorization, Kurrien (2005) identified four main types of schools:

1. English-medium middle-to-high-cost private schools in which teachers are proficient in English, but students have various levels of English exposure in their environment.
2. English-medium low-cost private schools in which teachers have limited English proficiency and students have little or no English exposure in their environment.
3. Government-aided regional schools in which teachers use limited English in conjunction with other regional languages with students coming from a variety of backgrounds.
4. Government aided-regional schools, run by local educational authorities, where teachers have the least amount of English proficiency and students have the least amount of English exposure.

Nearly half of India's school-going children are enrolled in private schools (Unified District Information System for Education, 2019 as cited in Central Square Foundation, 2020). Along with the belief that private schools provide better learning environments than government schools, many parents choose private schools for English-medium instruction (National Sample Survey Organization, 2014 as cited in Central Square Foundation, 2020). In 2019, approximately 42% of private schools offered English as a medium of instruction in their schools, compared to only about 10% of government schools (U-DISE, 2019 as cited in Central Square Foundation, 2020). However, in response to demand, government schools are increasingly offering English as a medium of instruction.

With a rise in the number of schools offering instruction in English, the Ministry of Human Resource Development recognized a need to understand the quality of English instruction in schools (Dutta & Bala, 2012). The study, which examined 154 primary schools across seven states and one union territory, highlighted the deficiencies present in the system. Teachers were heavily reliant on textbooks, adhering only to written words and printed instructions. Textbooks, however, did not focus on developing speaking and listening skills, nor did they allow children to build familiarity with the language. Classrooms lacked visible print, and teachers emphasized developing reading and writing over speaking and listening. Reading instruction followed four common practices: reading aloud, choral reading, silent reading, and pair reading. Nearly 80% of teachers predominately used reading aloud, whereas only 5% emphasized pair reading. Writing instruction typically involved copy-writing text presented to students on the blackboard. A majority of students played a passive role in the learning process with only 5-10% asking questions during lessons. In general, children were heavily reliant on rote reading and writing, and most oral-language activities were found to be memorized and repeated.

Government schools in India provide free education, making them one of the most widely accessible schooling options in the country. However, many children who enter government schools are coming from marginalized backgrounds and unfortunately, many of these schools struggle to provide these children with a high-quality teaching and learning experience (Dutta & Bala, 2012). These difficulties are further compounded when teachers are attempting to teach, and students are attempting to learn, in a language which they do not completely understand.

The studies in this dissertation specifically focus on primary school children attending English-medium government schools in India. The majority of children came from lower-income households and did not have exposure to English outside of the school environment. Teachers in the schools included in the studies had some command of English, but often used a mixture of both English and Hindi when instructing students. Most of the teaching was done through textbooks, and while classrooms had print in the form of instructional charts on the walls, children did not have access to other print material or a classroom library.

1.4 Foundational Skills and Early Reading Acquisition

Unlike spoken language, which is typically easily acquired through environmental exposure, reading is a highly complex skill which requires explicit instruction and practice. Fundamental to reading, across languages, is the ability to map sounds in the spoken language to their corresponding written form. There are differences between languages in how exactly speech maps onto print, thus, understanding the nature of the writing system is critical (Castles et al., 2018). The ease with which these grapheme-phoneme correspondences can be learned are affected by the orthographic depth of a language. In languages with shallow orthographies, there are consistent relationships between graphemes and phonemes, whereas in languages with deep orthographies, there is a greater degree of inconsistency. Studies comparing reading acquisition across languages have found substantial impacts of orthographic depth on the rate at which children develop accurate and fluent decoding ability (e.g., Seymour et al., 2003).

English is an alphabetic orthography in which speech sounds (phonemes) are represented by letters or groups of letters (graphemes). As a result, learning to read in English requires the acquisition of the alphabetic principle- an understanding that graphemes represent phonemes (Castles et al., 2018). Central to the acquisition of the alphabetic principle are phonological awareness and letter knowledge (Byrne & Fielding-Barnsley, 1989). Letter knowledge includes an understanding of the name, shape, and sound(s) of a letter (Ehri, 2020). Phonological awareness is defined as the ability to identify and manipulate various units of speech sounds such as syllables, onsets-rimes, and phonemes in spoken language (Piasta & Hudson, 2022). An aspect of phonological awareness is phonemic awareness, which specifically refers to the ability to identify and manipulate individual phonemes. Phonemic segmentation is necessary for children to detect individual phonemes within a speech stream (Ehri, 2020). Taken together, letter knowledge and phonemic awareness are skills which are foundational to children's understanding of how speech maps to print. Morphological awareness, which has generally been defined as the ability to identify, reflect on, and manipulate morphemes which are the smallest units of meaning in a language (see. Apel, 2014), is another important contributor to early literacy development (e.g., Kirby et al., 2012). Learning to read requires both morphological and phonological awareness.

According to Ehri's Phase Theory, the development of word reading consists of four phases: pre-alphabetic, partial alphabetic, full alphabetic, and consolidated alphabetic (see Ehri, 2020). Children are in the pre-alphabetic phase prior to their acquisition of the alphabetic principle. During this stage, children find it easier to learn to read words that are visually distinct and non-phonetic versus words which are spelled phonetically (see Ehri & Wilce, 1985). In addition, it is difficult for pre-alphabetic readers to identify environmental print when it is presented to them out of context, indicating that at this stage readers are not attending to letters (Levin & Ehri, 2009; Masonheimer et al., 1984). When children acquire alphabetic knowledge, they move into the partial alphabetic phase. In this phase, children can more easily learn to read words which are spelled phonetically as they learn letter-sound relations (Ehri & Wilce, 1985). However, children in the partial phase are often unable to decode new or unfamiliar words. With increased instruction and practice, children move into the full alphabetic phase where they are able to use their knowledge of grapheme-phoneme relations to decode new words. With extensive experience and instruction, children enter the consolidated alphabetic phase when they acquire and are able to apply knowledge of multi-letter spelling-sound units to read words. Studies have indicated that older children who struggle to read behave similar to early readers that are in the partial alphabetic phase (see Ehri & Wilce, 1983); meaning that they have not developed a complete understanding of grapheme-phoneme correspondences. Findings from studies which have informed our understanding of reading development shine a light on the importance of helping children build strong foundational literacy skills, particularly an understanding of grapheme-phoneme correspondences, and the impact this has on later stages of reading.

Despite the importance of the alphabetic principle to children's foundational English reading development, literacy instruction in many classrooms across India does not focus on building children's letter-knowledge and phonological awareness skills (Khan & Khan, 2021). Particularly in government schools, English word reading is taught using the "ABC" or alphabet-spelling method (Gupta, 2014; Rayner et al., 2001). Through this method, children are taught letter names which are then used to spell words. Consequently, there is either no letter-sound instruction or letter-sound instruction, which is limited to one sound per letter, leaving children reliant on rote-memorization of whole-words (Dutta & Bala, 2012; Gupta, 2014). Given the nature of the English language, acquisition of the alphabetic principle is critical. Understanding how children in India can be supported in learning these skills when it is most developmentally appropriate is fundamental to improving literacy learning.

1.5 Cross-Language Relations in Multilingual Learners

An extra layer of complexity is added to the process of reading development when children are learning to read in a language that they are simultaneously learning to speak and understand; a common situation faced by children in India. In line with the three-language formula, children attending English-medium schools will learn English as the first literacy language and the regional or state language as an additional subject. Understanding the developmental relationship between L1 and L2 language and literacy skills is needed to help inform instruction and intervention in such contexts.

An early and influential theory on multilingual literacy acquisition, Cummins linguistic interdependence hypothesis (Cummins, 1979), posits that the L1 and L2 are interdependent as a result of a common underlying proficiency which is shared. Consequently, development of the L1 can facilitate development of the L2. The ability to leverage skills from the L1 when learning to read in an L2 is referred to as cross-linguistic transfer (see Genesee et al., 2006). The nature of transfer was not clearly specified by Cummins' hypothesis. According to the transfer facilitation model (Koda, 2008), it is metalinguistic awareness, specifically phonological and morphological awareness, that once developed in the L1 can be transferred to facilitate L2 reading. Phonological awareness has long been an area of focus in studies of multilingualism because although it is believed to follow a universal developmental sequence, with children developing sensitivity to large phonological units (e.g., syllables and onset-rime) before developing sensitivity to smaller phonological units (e.g., phonemes), the rate at which these skills develop vary as a function of orthographic differences between languages (Zeigler & Goswami, 2005).

A large body of research examining literacy acquisition among bilingual learners has focused on the relationship between L1 and L2 phonological awareness and word reading. In general, findings have indicated that there is in fact bidirectional transfer of phonological awareness, with skills in one language facilitating reading in another (see Gottardo et al., 2021 for review). Although phonological awareness is viewed as being language universal, the extent to which phonological awareness and word reading skills are related vary across language pairs (Branum-Martin et al., 2012; Branum-Martin et al., 2015).

Only a few studies have specifically examined cross-language transfer among bilingual children in India. Among 9-year-old children who were L1 speakers of Oriya and who were attending school in Oriya, there was evidence of bidirectional transfer with phonological awareness in Oriya and English predicting word reading in English and Oriya respectively (Mishra and Stainthorp, 2007). However, for children who were L1 speakers of Oriya but who attended English-medium school, there was transfer from L1 to L2 (Oriya phonological awareness to English decoding) but not from the L2 (English phonological awareness) to the L1 (Oriya decoding). In a second study with 10 to 14-year-old L1 speakers of Kannada who were attending Kannada medium school but studied English as a subject, there was evidence of a cross-language contribution of Kannada phonological awareness to English decoding, but this relationship was mediated by English phonemic awareness (Reddy & Koda, 2013). The findings of these studies highlight the contributions of L1 to L2 literacy and how they vary as a function of contextual factors such as instructional medium and linguistic factors such as script. Prior to this dissertation, there was a gap in the literature examining cross-language transfer in Hindi-English bilinguals who were emergent readers. Prior studies in India have focused on older bilingual readers with sufficiently developed literacy skills in their L1. In order to determine how children's L1 can be leveraged in building their foundational English literacy skills, it is important to understand the role of cross-language transfer in emergent readers.

1.6 Phonics Instruction

Decades of research has informed what we know about how children learn to read. Yet, specifically in regard to English, there has been continued debate on how exactly children should be taught to read. The "reading wars" have been fought by two major parties; one which favors a systematic phonics approach and another which favors a whole-language approach (Castles et al., 2018). Proponents of the whole-language approach believe that explicit instruction of the code is unnecessary. Reading is viewed as a "psycholinguistic guessing game" in which children are able to read words by using context clues and background knowledge (Goodman, 1967). On the contrary, proponents of the phonics approach believe that children should be explicitly taught letter-sound correspondences; the "code" of the language (Chall, 1967). Systematic phonics, which refers to "reading instruction programs that teach pupils the relationships between graphemes and phonemes in an alphabetic writing system" typically in an ordered manner, has long been the instructional method supported by research on reading development (see Castles et al., 2018). Consequently, this dissertation adopts the perspective that systematic phonics instruction is the most appropriate instructional method for foundational English literacy.

Phonics involves both grapheme-phoneme and phonemic awareness instruction, as well as instruction on how to use that knowledge to decode and spell words (Ehri, 2020). Phonemic awareness is known to facilitate decoding and has been identified as one of the strongest predictors of individual differences in word reading ability (Melby-Lervåg et al., 2012). Studies have shown that explicit instruction, in which children are taught to identify and manipulate phonemes in spoken words, can be effective at developing children's phonemic awareness skills (Foorman et al., 2016; National Reading Panel, 2000; Rice et al., 2022). Additionally, providing children with explicit and systematic instruction of grapheme-phoneme correspondences in which they are also taught how to blend sounds to form words is critical (Ehri, 2003). An area of debate among researchers has been around the optimal spelling-sound unit of early reading instruction (e.g., Goswami, 2002; Hulme et al., 2002). English, as an opaque orthography, has a great degree of inconsistency at the level of phonemes but much less inconsistency at the level of the rime (Treiman et al., 1995). In addition, phonological sensitivity develops in a hierarchical manner with children developing syllable awareness before onset-rime awareness, and onset-rime awareness before phoneme awareness (e.g., Anthony & Lonigan, 2004). As a result, some researchers have argued in favor of phonics instruction which is not just based on individual grapheme-phoneme correspondences (e.g., "bat" is "b"- "a"- "t") but rather which emphasizes larger units, specifically onset-rimes (e.g., "bat" is "b"- "at") (Zeigler & Goswami, 2005). Along with greater consistency, an emphasis on rime is believed to facilitate early reading by allowing children to tap into their existing phonological awareness as onset-rime awareness is not dependent on literacy instruction (Goswami & Bryant, 1990). However, given that alphabetic languages represent speech at the level of the phoneme, grapheme-phoneme knowledge is still required for reading (Ehri, 2020).

There is now an extensive research base that has informed our understanding of the effectiveness of phonics instruction. In 2000, the National Reading Panel released the findings of a meta-analysis evaluating the effectiveness of systematics phonics instruction as compared to nonsystematic or non-phonics-based instruction in the United States. Across 66 treatment-control comparison groups, it was seen that phonics instruction was moderately effective (*d*= .41). This effect was higher when instruction began early (*d*= .55) and decreased greatly if instruction was provided after Grade 1 (*d*= .27). Similar findings were observed in studies conducted in Australia (Rowe, 2005) and the UK (Rose, 2006).

Although English learners face the additional challenge of learning to read in a language they are simultaneously learning to speak and understand, the skills that English learners require to read in English are the same as those which L1 English speakers require (Goldenberg, 2020). English learners must similarly learn how graphemes represent phonemes, and how these are combined to form words. As a result, there is reason to assume that methods of literacy instruction that have been found to be most effective would be equally applicable to both groups of children. In a recent meta-analysis examining the effect of phonemic awareness instruction on children's phonemic awareness skills, researchers found no significant effects of reading difficulty status or English language learner status indicating that phonemic awareness instruction is generally effective for all students (Rice et al, 2022). In a review of literacy learning among English learners conducted by the National Literacy Panel on Language-Minority Children and Youth, it was found that explicit phonics instruction benefited English learners as much as native English speakers (August & Shanahan, 2006; see also August et al., 2014). A more recent meta-analysis examining the effect of L2 English phonological awareness and/or phonics instruction across 35 studies similarly found a moderate effect on word reading (g= .53) and a large effect on pseudoword reading (g= 1.51) (Odo, 2021).

There are only a few studies which have examined the effects of phonics instruction with English learners in India. Dixon, Schagen, and Seedhouse (2011) studied the effectiveness of a phonics-based intervention with Grade 1 students (mean age = 7 years) who were attending low-cost private English-medium schools in slum areas of Hyderabad, India. Students in the experimental group received 1-hour of phonics instruction per day which was designed based on the Jolly Phonics program (Lloyd, 1992). Instruction was offered by a teacher which was hired and trained by the researchers. Students in the control group received business-as-usual instruction from their class teacher. After a 6-month intervention period, students in the intervention group significantly outperformed students in the control group on measures of reading and spelling, indicating that phonics-based instruction is effective even for children from slum communities who did not have English language exposure outside of school. Phonics-based instruction has also been found effective when used with older children (Grade 5) who started school in their regional-medium but started learning English in Grade 3, in line with what is prescribed by India's three-language formula (Nishanimut et al., 2013). Researchers compared the effects of traditional phonics instruction, phonics instruction which involved teaching English letter-sounds by mapping them back to the symbols in children's L1 (Kannada Akshara), and business-as-usual instruction. The intervention sessions were led by teachers trained by the researchers and the business-as-usual instruction was carried out by a qualified primary school teacher. After a 5-week intervention period, students in both the traditional phonics and the Kannada-based phonics groups performed better than the control group on measures of phonological awareness, reading, and spelling. However, the Kannada-based phonics group also outperformed children in the traditional phonics group. For English learners with a well-established L1, it may be possible to enhance the effects of phonics-based instruction by leveraging children's existing metalinguistic awareness. More recently, Shenoy et al. (2020), who compared English reading skills across children who were attending low-, middle-, and high-cost schools in Bangalore, India found that children who attended Montessori schools (high-cost) were the only group, as compared to students in low- and middle-cost schools, who were at par with US normed reading measures across Grades 1, 3, and 5. This was also the only group of students who were receiving phonics-based literacy instruction in school. Overall, the case for using phonics-based instruction for children attending English-medium schools is promising. However, the existing studies still leave many important questions regarding the generalizability of findings and the practicality of implementation.

1.7 Educational Technology for Supporting Effective Instruction

1.7.1 The Promise of Educational Technology

India has long been a strong player in the educational technology, or "ed-tech" market, which is estimated to be worth over $4 billion US dollars by 2025, of which $1.5 billion will be directed towards K-12 education (India Brand Equity Foundation, 2021). India, like many low- and middle-income countries, sees promise in the ability of technology to remediate and enhance teaching and learning, particularly as technologies become increasingly affordable and accessible. Studies focusing on ed-tech solutions in India, and other low and middle-income countries around the world, have pointed to some notable benefits including the ability to scale high-quality content, provide learners with personalized instruction and feedback, and expand opportunities for practice (Banerjee et al., 2007; Muralidharan et al., 2019; see also Ganimian et al., 2020 for review). All of these factors greatly affect school systems in India and have significant impacts on student learning.

The teacher shortage in India is not as prevalent as is often believed (see Datta and Kingdon, 2021), however, teacher absenteeism is a significant issue that has been identified as a contributor to poor educational outcomes (Duflo et al., 2012). In rural areas, nearly a quarter of teachers are absent on any given day (Muralidharan et al., 2017). Even in classrooms where teachers are present, many lack the knowledge required to provide students with high quality instruction. Teachers in English-medium government schools across India have, oftentimes, not received adequate training to prepare them for their role. It is not uncommon for teacher training candidates to have studied in their mother tongue and often themselves have limited exposure to English (Ali, 2022). Consequently, many teachers are left heavily reliant on rote methods of instruction (Dutta & Bala, 2012). Additionally, increased access to schooling has resulted in large variations in student skills. It is estimated that in any given classroom, student learning levels can vary 4 to 5 grade levels (Banerji, 2018); a finding that has been identified as a critical constraint of the Indian education system as teachers struggle to cater to the individual needs of students (Dyer, 2008).

Generally, studies examining the efficacy of ed-tech in improving instruction in low- and middle-income countries have shown medium to large effects (see Rodriguez-Segura, 2020 for review). In addition to general improvements in the quality of instruction and content, a significant appeal of ed-tech is the ability to provide learners with instruction that is personalized. In India, as in many other developing countries, adaptive technologies in which content is adjusted to student ability allow for a level of differentiated instruction, practice and feedback which would be extremely difficult for a teacher alone to provide. Technologies which support personalized learning have generally shown positive effects, with adaptive technologies which adjust to the players performance showing even greater effects (Major et al., 2021).

Despite heavy investments, research on the effective use of educational technology in India has been limited. At the government level, there has been a large focus on providing schools with infrastructure (e.g., computer labs) with little focus on curriculum integration (see Central Square Foundation, 2015). However, research has shown that simply providing hardware does not improve student learning (e.g., The One Laptop Per Child Program in Peru; Cristia et al. 2017). The few studies that have been done in India have indicated that the interventions in which there are the largest gains are those in which technology allows for personalized instruction. A notable study by Banerjee et al. (2007) indicated that a computer-assisted program specifically focused on supporting math skills at the individual child's level did in fact lead to increased scores even one-year post-intervention. More recently, Muralidharan et al. (2019) examined the effectiveness of Mindspark, a widely used instructional software. Middle school students (Grades 6 to 9) who were from low-income neighborhoods were recruited to participate in a 4.5-month intervention examining the efficacy of Mindspark in improving math and Hindi scores of students who were 2.5 to 4.5 grade levels behind grade level at the start of the intervention. Results indicated significant improvements in children's math and Hindi test scores with no variation by baseline score, gender, or socioeconomic status. By providing ed-tech support, which was individualized for the learner, all students were able to benefit. While existing studies have been informative, there are still many gaps in evidence (see Sampson et al., 2019) warranting a need for rigorous evaluation studies in classrooms across India.

1.7.2 GraphoLearn

GraphoLearn, originally known as GraphoGame, was developed after findings derived from the Jyväskylä Longitudinal Study of Dyslexia indicated that children at risk for dyslexia have speech perception difficulties which limit their ability to connect graphemes to phonemes (Lyytinen et al., 2009). Given that Finnish is a transparent orthography in which letter-sound correspondences are always the same, GraphoLearn was originally developed in Finnish with the premise that these correspondences can be quickly and efficiently drilled

(Lyytinen et al., 2009). With the general goal of teaching the connections between spoken and written language, GraphoLearn has since been studied in over 20 countries in a variety of languages (see McTigue et al., 2019 for review). In all game versions, content is presented starting with small units (e.g., single graphemes and phonemes) which build up to increasingly larger units (e.g., words). Within language versions, however, content varies in terms of sequence and amount.

Figure 2 Screenshot of a letter-sound task from GraphoLearn English Rime

GraphoLearn uses an animated player interface in which an avatar moves through various play screens (see Figure 2). The main task involves a small number of written symbols (letters or text segments) which players are required to match with auditorily presented speech sound (phoneme, syllable, or word). Additional levels scattered throughout the game require players to move tiles containing individual graphemes into the correct order to form an auditorily presented word, supporting both decoding and spelling skills. Once players make a selection, they are provided with explicit feedback. If the player makes an incorrect selection, they are guided to the correct match or word configuration, after which the same symbol-sound pair is presented again allowing for additional practice. When a correct selection is made, players are notified and subsequently rewarded with stars and tokens which can later be traded in to make modifications to their avatar. Across all game versions, players progress through the game at their own pace as content adapts to player performance, allowing for individualized play and practice.

In 2019, McTigue et al. conducted a meta-analysis synthesizing findings across 19 studies which had examined the efficacy of GraphoLearn in various languages and countries around the world. Across these studies, it was found that GraphoLearn typically led to improvements on subskills of reading, but this did not translate to significant growth in children's word reading skills (g= -0.02, p= .70). The meta-analysis also indicated that studies in which there was a positive effect of GraphoLearn on reading were those in which there was a high degree of adult interaction (g= .47) (e.g., Saine et al, 2011). Studies examining the Finnish version of GraphoLearn (known in Finnish as 'Ekapeli') have typically implemented GraphoLearn as a part of more integrated instruction and have generally shown positive improvements in children's literacy-related skills, specifically among poor and/or at-risk readers. (e.g., Heikkilä et al., 2013; Hintikka et al., 2005; Saine et al., 2010, 2011).

Recognizing the potential of GraphoLearn as a tool towards improved literacy skills, GraphoLearn was taken to Africa, which like India, has long grappled with poor literacy outcomes. GraphoLearn was first studied in Zambia with children who were learning to read ciNyanja, a Bantu language. The Bantu languages, like Finnish, are orthographically transparent giving researchers a reason to believe that a similar intervention could be effective. GraphoLearn, when used only by students, only by teachers, or by both teachers and their students was studied in comparison to students who received "business-as-usual" instruction (Jere-Folotiya et al., 2014). GraphoLearn resulted in significant improvements when used only by the students but also when used only by the teachers, indicating that GraphoLearn can not only be used as a learning tool for students but also as a training tool for teachers. The strongest effect, however, was seen when both teachers and their students were able to play GraphoLearn. Following the success of GraphoLearn in Zambia, variations of the game were introduced in Kenya, Tanzania, and Namibia. In Kenya, the effectiveness of GraphoLearn was assessed for Kiswahili and Kikuyu with children who were second language learners (Puhakka et al., 2015). Similarly, GraphoLearn was examined in Tanzania with children who were learning to read Kiswahili (Ngorosho, 2018). In Namibia, GraphoLearn was implemented with children learning to read Afrikaans (February, 2018). These studies shed light on the use of GraphoLearn in countries which are dealing with many of the same challenges as seen in India. More specifically, there was evidence for the use of GraphoLearn in environments where students are learning to read in a language which may not be their mother tongue (e.g., Puhakka et al., 2015) and where teachers are lacking the skills required for effective literacy instruction (e.g., Jere-Folotiya et al., 2014).

1.7.3 GraphoLearn English Rime

Unlike Finnish, which is a transparent orthography due to its near one-to-one mapping of graphemes to phonemes, English is an opaque orthography which contains one-to-many mappings between graphemes and phonemes. Thus, when GraphoLearn was developed for English, this inconsistency had to be considered. For GraphoLearn English Rime, the version of the game used for this dissertation, content was adapted based on the view that children learning to read English may benefit from a greater focus on rime (Goswami & Bryant, 1990). In line with this, content for GraphoLearn Rime is organized on the basis of rime families so that, in addition to individual grapheme-phoneme correspondences, families with the most common and consistent orthographic rimes are introduced first.

Content is organized across 25 play streams, within which there are multiple levels. As in all versions of GraphoLearn, players are first introduced to a small subset of individual phonemes and/or rime units which they practice across levels within each play stream. They are presented with a speech stream which they are required to match with the correct written unit on the screen. GraphoLearn English Rime supports phonological awareness development through rhyme awareness levels in which players are required to match the auditorily presented word to the rhyming written word. Spelling is development is also further supported through word formation tasks in which players drag tiles containing graphemes into the correct order to form the auditorily presented word.

In order to move to the next, more difficult, stream players are required to achieve 80% accuracy across all of the levels within a given stream. After every four play streams, players reach an assessment stream. In total, GraphoLearn Rime contains seven assessment streams, all of which contain the same content. Players are assessed on individual letter-sound recognition, rime unit recognition, and word recognition. In the assessment streams, unlike in the play streams, players are not provided with feedback and progress to the next play stream after completing the assessment stream regardless of their performance.

The efficacy of GraphoLearn Rime was first assessed with 6-7-year-old students (Year 2) in the UK, where the use of synthetic phonics in Year 1 is government mandated. The game was used as a supplement to classroom instruction for students who were identified as poor readers and resulted in medium to large effects on measures of word reading and spelling (d= 0.53-1.43) (Kyle et al., 2013). A large-scale randomized controlled trial study of nearly 400 Year 2 students in the UK found GraphoLearn to be as effective as business-as-usual instruction (g= 0.01-0.06) (Worth et al., 2018).

1.8 Aims of the research

The overall aim of this dissertation was to add to the limited body of existing research focused on understanding literacy development of children attending English-medium schools in India. More specifically, this dissertation examines the efficacy of a computer-assisted phonics intervention for supporting foundational English literacy learning across a series of three studies. The first study was a small-scale pilot designed to examine the efficacy of GraphoLearn English Rime, a computer-assisted, phonics-based intervention, to improve foundation English literacy skills of Grade 3 children attending an English-medium school in India. Learnings from the first study were then taken and a second study was conducted in which GraphoLearn was examined with a larger sample of Grade 1 and 2 students attending an English-medium government school in India. In the third study, data collected on Grade 1 and 2 students' L1 (Hindi) literacy skills were examined in conjunction with data on students' L2 (English) literacy skills to understand the relationship between L1 and L2 literacy skills, and specifically the role of cross-language transfer of phonological awareness skills.

2 METHODS

2.1 Research Ethics

All of the phases of data collection were designed and conducted in line with the requirements as set forth by the University of Jyväskylä Ethics Committee and following the University of Jyväskylä principles of data protection.

In the first phase of data collection (Study I), written permission was taken from the Ahmedabad Municipal School Board to collect data in the school. Permission to conduct the study was also taken from the school principal and classroom teacher. The parents of the children also provided written informed consent. In the second phase of data collection (Study II and Study III), permission to conduct the study was taken from the school principal and the respective classroom teachers. Once again, parents provided written informed consent on behalf of their children.

Across all of the studies, participation on behalf of the schools, teachers, and students was completely voluntary. It was communicated that any of the parties were able to refuse participation at any time and that the studies had been designed to ensure that no harm was done to the participants. Parents were provided with consent forms in both Hindi and English to ensure full understanding. Once collected, data was fully anonymized and stored on a secure drive.

2.2 Intervention Fidelity

In the two studies involving GraphoLearn intervention (Study I and II), fidelity was controlled by logs which were sent directly to the GraphoLearn server. The logs included the days played and the time spent playing by children in the GraphoLearn group. Student attendance to the intervention sessions was also recorded by the researcher. Furthermore, the researcher was present in all of the sessions to ensure that students were engaged in playing their respective games.

3 OVERVIEW OF THE ORIGINAL STUDIES

3.1 Study I

GraphoLearn India: The effectiveness of a computer-assisted reading intervention in supporting struggling readers of English

3.1.1 Aim

The aim of the first study was to use a randomized controlled trial intervention design to examine the efficacy of GraphoLearn English Rime when used with Grade 3 English learners in India. Specifically, we examined whether children who play GraphoLearn significantly outperform children who do not on measures of foundational English literacy skills.

3.1.2 Participants

The first study included a sample of 31 Grade 3 students (ages= 7-8 years) who were attending an English-medium public school in Ahmedabad, Gujarat, India. All of the children in this study came from low-income homes in the community which surrounded the school. The predominant home languages were Gujarati, the state language, and Marwari, a language from the neighboring state of Rajasthan. All of the children were learning English as a second or third language and there was limited exposure to English outside of school. After being matched on age and gender, students were randomly allocated to either the GraphoLearn group (n= 16) or the math game control group (n= 15). The data for one student from the control group was removed prior to analysis due to missing posttest data and as a result, the final group sizes at posttest consisted of 16 children in the GraphoLearn group and 14 children in the control group of which 15 were boys and 15 were girls.

3.1.3 Procedure

For the intervention sessions, students were pulled out of their classroom in groups of 12 and brought to a separate room where they played either GraphoLearn or a math game on individual tablets equipped with headphones. Sessions ranged from 20-30 minutes per day and were conducted six days per week, during children's regular school hours.

Students in the control group played "Math for Kids" a Grade 3-level game which was selected from the Google Play Store. The game provided students with basic math operations which they had to solve by selecting the correct response out of the four provided options. In the math game, as in GraphoLearn, students proceeded through multiple levels of increasing difficulty at an individual pace, however, players of the math game received no auditory input in English. The main purpose of using the math game with the control group was to ensure that both groups of children were being exposed to technology and spent equivalent amounts of time out of the classroom.

3.1.4 Measures

Data on students' English literacy skills were collected prior to the start of the intervention as well as after using both an in-game assessment built directly into the GraphoLearn software as well as four standardized paper-pencil tasks.

The GraphoLearn in-game assessment consists of a letter-sound knowledge task, a rime unit identification task, and a word recognition task. In all of the tasks, the players are required to identify the correct visual response which matches with the auditorily presented item. The letter-sound task consists of 24 trials in which players are required to pick the correct letter (grapheme) out of the auditorily presented phoneme. The rime unit task consists of 24 trials in which players are required to select the correct letter string which corresponds with the pronunciation presented to them. The word recognition task consists of 47 trials in which players are required to pick the correct word out of the visually presented options. All of the trials of the letter-sound task are presented regardless of performance. However, the rime unit and word recognition tasks discontinue once players select an incorrect response on 50% of the presented trials.

Students were also assessed on four standardized oral and paper-based measures which included the single word reading and spelling subtests from the British Ability Scale II (BAS II; Elliot et al., 1996) and the sight word and nonword subtests from the Test of Word Reading Efficiency (TOWRE; Torgesen et al., 1999). The single word reading test from the BAS II requires children to read aloud a set of words which are presented in order of increasing difficulty. The TOWRE reading tasks require children to accurately read aloud a list of sight words and nonwords within 45 seconds. To assess children's spelling skills, 30 words from the BAS II spelling task were presented as a whole-class dictation.

3.1.5 Results

After an 8-week intervention period, results indicated that students in the GraphoLearn group showed greater and faster development on the in-game measure of letter-sound knowledge as compared to students who did not play GraphoLearn. There were no significant differences between the groups on the GraphoLearn in-game rime units and word recognition tasks. There were also no significant differences between the groups on the oral and paper-based measures. Overall, results showed that even after a limited intervention period, GraphoLearn has the potential to support the development of letter-sound knowledge which is a critical skill required for early literacy.

3.2 Study II

Assessing the effectiveness of a game-based phonics intervention for first and second grade English language learners in India: A randomized controlled trial

3.2.1 Aim

The aim of the second study was to, once again, use a randomized controlled trial to examine the efficacy of GraphoLearn English Rime in improving the foundational literacy skills of children who were attending English-medium school in India. Based on learnings from the first study, the intervention was conducted with a younger sample of students and using a larger set of oral and paper-based measures which were validated for use with children in India. In addition to efficacy, we examined how progress in GraphoLearn relates to children's performance at pre- and post-test and whether there are differences in effectiveness as a result of these relations.

3.2.2 Participants

Based on learnings from the pilot study, for the second study we chose to test GraphoLearn with a younger sample of children. The study included 143 Grade 1 and 2 students (ages= 5-7 years) who were attending an English-medium public school in Delhi, India. Over 80% of the sample came from homes where only Hindi was used and all of the children were learning English as a second or third language. The school contained three Grade 1 classrooms and three Grade 2 classrooms all of which were involved in the study. Within each class, students were matched on age and gender and then randomly assigned to either the GraphoLearn group or the math game control group. Data from seven students was removed due to missing data resulting in a final sample of 136 (GraphoLearn= 69, control= 67) of which 69 were boys and 67 were girls.

3.2.3 Procedure

For the intervention sessions, students were brought class-by-class into a separate room in the school where they played either GraphoLearn or a math game on smartphones equipped with headphones. Sessions were conducted for 20 minutes a day, 5 days a week, during regular school hours. Students in the control group played "Math Kids- Add, Subtract, Count, and Learn" selected from the Google Play Store. In "Math Kids", players practiced counting, comparison, and basic operations; skills that students were learning as a part of their math curriculum in school. The math game, similarly to GraphoLearn, was structured so that students played under the same profile each session. Although the math game did not have a pre-set play sequence, students were monitored to ensure they were playing different levels each week to maintain motivation and learning. All of the auditory and visual input in the game was presented in Hindi to ensure that children in the control group were not receiving additional English exposure. As with the first study, the main purpose of using the math game with the control group was to ensure that both groups of children were being exposed to technology and spent equivalent amounts of time out of the classroom.

3.2.4 Measures

As in the first study, children were assessed prior to the start of the intervention and immediately after. The GraphoLearn in-game assessment was used along with a new and larger set of oral and paper-based measures. The oral and paper-based tasks were taken from the English version of the Dyslexia Assessment of Languages of India (DALI; Rao et al., 2021; Singh, 2015). The DALI is one of the first validated and standardized assessment tools designed for the assessment of children's literacy skills in India. Children's phonological awareness skills were assessed using an oral rime identification and phoneme replacement task, fluency skills were assessed using a measure of verbal and semantic fluency, reading skills were assessed through a letter naming task and a word reading task, and spelling skills were assessed through a letter spelling task and a word spelling task. In addition to the DALI measures, children were assessed using a pseudoword reading task and a second, slightly more difficult, word reading task developed by Cherodath and Singh (2015) for use with children in India.

3.2.5 Results

After a 5-week intervention period, results indicated that children in the GraphoLearn group showed significantly greater and faster development across all of the GraphoLearn in-game assessment measures compared to children who did not play GraphoLearn. However, as with the first study, there were no significant differences between the groups on the oral and paper-based measures. We also investigated individual differences in learning from the game by further examining the group of children who played GraphoLearn. Correlations examining the relationship between progress in GraphoLearn, and pre- and post-test scores showed that while players who made greater progress in GraphoLearn had higher post-test scores, they also had higher pre-test scores. We then reexamined the full sample of students to examine any potential differences in game effectiveness based on children's preexisting skill level. Median splits on a composite score of the pre-test measures was used to divide children into two groups, those who had higher preexisting English skills and those who had lower preexisting English skills as assessed by the pre-test measures. Results indicated a stronger effect of GraphoLearn among children with stronger pre-existing English skills, at least on the GraphoLearn in-game assessment tasks. However, even among children with stronger pre-existing English skills there was no effect of the intervention on the oral and paper-based measures.

3.3 Study III

Understanding the role of cross-language transfer of phonological awareness in emergent Hindi-English biliteracy acquisition

3.3.1 Aim

The aim of the third study was to understand the relationship between L1 and L2 literacy skills, specifically the role of cross-language transfer of phonological awareness skill, among children who were learning to read both Hindi and English in India. There is a significant amount of previous research which has examined the cross-language transfer of children's phonological awareness skills from their first language (L1) to their second language (L2), and vice versa. However, these studies have largely ignored the Indian subcontinent. Using pre-test data that was collected from children who took part in the second study, we examined the associations between phonological awareness in children's L1 (Hindi) and phonological awareness in children's L2 (English), and how these were related to children's L1 (Hindi) and L2 (English) decoding.

3.3.2 Participants

The third study utilized pretest data which was collected as a part of the second study and included the full sample of 143 children across Grades 1 (n= 70) and 2 (n= 73). The Grade 1 sample consisted of 43 boys and 27 girls (M_{age}= 5.73, SD= .45). The Grade 2 sample consisted of 31 boys and 42 girls (M_{age}= 6.68, SD= .47).

3.3.3 Measures

Data collected using the oral and paper-based tasks of the DALI was utilized for the study. In addition to the English tasks, children were assessed using a set of matched measures from the Hindi DALI (Rao et al., 2021; Singh, 2015) and two additionally developed measures (Cherodath & Singh, 2015). The skills assessed were rapid automatized naming (RAN), semantic fluency, rime oddity, word reading, and pseudoword reading. The tasks used for phonological awareness were not equivalent across the two languages given that for Hindi, an Akshara replacement task was used whereas for English a phoneme replacement task was used.

3.3.4 Results

Results indicated that phonological awareness skills in each language were predictive of decoding in that language, providing evidence in support of the critical role of phonological awareness in reading. In Hindi, Hindi syllable replacement emerged as the strongest unique predictor of Hindi word reading. On the contrary, in English, phonemic awareness emerged as the single strongest predictor of decoding. These results are reflective of the orthographic properties of the respective languages and also indicate that critical requirement in improving English literacy skills among children in India is supporting the development of children's phonological awareness skills, and specifically phonemic awareness, in English. In line with previous studies, results also showed that phonological awareness skills in Hindi (L1) significantly predicted word reading in English (L2). Hindi rhyme awareness (but not Hindi syllable awareness) continued to add a significant amount of unique variance to English word reading even after controlling for the effects of English phonemic awareness, indicating a role of cross-language transfer. English phonemic awareness (L2) also significantly predicted Hindi word and pseudoword reading (L1), however the effects were no longer significant once phonological skills in Hindi were controlled for.

4 DISCUSSION

A vast amount of research informs what we know today about how children learn to read. In alphabetic languages, such as English, speech sounds (phonemes) are represented by letters (graphemes). Therefore, children must develop an understanding of how graphemes map to phonemes to form a word. Systematic phonics, an instructional method which involves explicitly teaching the relationships between graphemes and phonemes, has long been found to be highly effective for teaching the foundational skills needed for decoding (see Castles et al., 2018; Rayner et al., 2001).

India has long struggled with poor literacy outcomes. Ineffective instructional practices, particularly a reliance on rote memorization and reproduction, have been identified as significantly contributing to the problem (UNESCO New Delhi, 2021). Studies which have examined the efficacy of phonics-based instruction in India have shown dramatic improvements in children's English reading skills (Dixon et al., 2011; Gupta, 2014; Shenoy et al., 2020). Despite the existing evidence base, many schools in India which offer English as a medium of instruction do not use a systematic phonics approach to teach foundational literacy skills (Gupta, 2014; Khan & Khan, 2021). In a country with nearly 10 million teachers, pedagogical reform is a serious undertaking.

Countries around the world have turned to ed-tech to help counter the effects of poor pedagogy and improve learning. Along with the ability to provide learners with instructional material that is of high-quality, perhaps one of the biggest draws of ed-tech across low- and middle-income countries is ability to provide personalized learning experiences (see Major et al., 2021). In India, experimental studies examining the efficacy of ed-tech interventions which allowed for personalized instruction have resulted in significant improvements in children's learning (Banerjee et al., 2009; Muralidharan et al., 2019). Much of this success has been attributed to the ability to provide every child with instruction and support which is at the correct level for them; something that is nearly impossible for even the best of teachers to provide.

This dissertation aimed to examine whether GraphoLearn English Rime, a computer-assisted, phonics-based reading intervention would be effective at improving the foundational literacy skills of children attending English-medium government schools in India. More specifically, Studies I and II examined the efficacy of GraphoLearn English Rime as a reading intervention. Study III focused on the examination of children's literacy skills in their first (Hindi) and second (English) languages.

4.1 Within- and Cross-language Predictors of Reading

Although Study III makes up the final part of this dissertation, the findings reaffirm the critical role of foundational skills for reading, and therefore will be discussed first. The relationships between L1 and L2 phonological awareness and L1 and L2 decoding have been examined across a variety of language pairs in speakers around the world. Meta-analyses have indicated a moderate to large relationship between L1 phonological awareness and L2 word reading (Melby-Lervåg & Lervåg, 2011). However, variations in the strength of these relationships have been found depending on the language pair (Branum-Martin et al., 2012; Branum-Martin et al., 2015). To better inform our understanding of English literacy skill development among children in India, we used data collected from Study II to examine the relationships within and across children's L1 (Hindi) and L2 (English). The study also fills a gap in existing literature which had not previously examined these relationships among this language pair (Hindi-English) and this age group (emergent readers).

The within language predictions reaffirmed the importance of phonological awareness in reading. In both Hindi and English, it was seen that phonological awareness in a language was highly predictive of reading in that language. In examining the relationship between English phonological awareness and decoding, phonemic awareness emerged as the single strongest predictor of decoding. This finding is in line with previous research which has identified phonemic awareness as one of the strongest predictors of individual differences in reading (e.g., Melby-Lervåg et al., 2012). This finding also supports previous research which has indicated that English learners require many of the same skills as native English-speaking children who are learning to read (Goldberg, 2020). Given the role that phonemic awareness plays in children's decoding ability, it is perhaps not surprising that phonics-based instruction which supports the development of children's phonemic awareness has also been found effective in India (e.g., Dixon et al., 2011).

Considering that phonological awareness is a skill that is shared across languages, there is an opportunity to increase the effects of literacy instruction and intervention which leverages children's existing knowledge and accounts for any differences between languages (Piasta & Hudson, 2022). Findings from the examination of the cross-language relationships between Hindi phonological awareness and English decoding, as well as the relationships between English phonological awareness and Hindi decoding provided evidence of cross-language transfer. Hindi phonological awareness, specifically Hindi rhyme awareness, predicted English word reading even after controlling for the effects of English phonemic awareness. Generally, these findings were in line with previous studies which have examined cross-language relationships (see Gottardo et al., 2021 for review). However, these finding also highlighted the differential contributions of phonological awareness skills to reading across varied language pairs. Despite English decoding being reliant on phoneme-level awareness, syllable-level awareness in Hindi made a meaningful contribution. Syllable-level awareness is one of the earliest available phonological units and is viewed as a universal in language processing (Zeigler & Goswami, 2005). According to the transfer facilitation model, it is non-language specific aspects of phonological awareness such as these which transfer across languages (Koda, 2008). Children were able to use this knowledge in their dominant language to support reading in their L2.

The findings reiterate the role that L1 literacy skills play in children's L2 literacy and opens the door for understanding how children's existing L1 knowledge can be better leveraged for literacy instruction in English-medium classrooms. Nishanimut et al. (2013), for example, leveraged the alpha-syllabic writing system of the Indian Akshara languages to provide 10-year-old children with phonics instruction in which English letter-sounds correspondences were presented along with the Kannada symbols, allowing children to tap into their existing knowledge. Children who received the Kannada-mediated phonics instruction outperformed those who received English-only phonics instruction, reflecting the benefits of using the L1 to learn the L2. Others have also found that it may be easier for teachers in India to instruct English phonics if the methodology is mapped to a system which teachers are more familiar with, such as the way that they instruct Akshara (Gupta, 2014). There is a great need to conduct further research to understand how the L1 can used to support both English instruction and English learning in India.

4.2 The Effectiveness of GraphoLearn as a Reading Intervention

There is increasing evidence supporting the use of phonics-based instruction to support the development of children's foundational English literacy skills in India (e.g., Dixon et al., 2011; Shenoy et al., 2020). Implementing phonics-based instruction across English-medium schools across India, however, is much easier said than done. Many teachers in India have learned English through the alphabet-spelling method and have not been trained to teach through phonics (Gupta, 2014). Perhaps an even greater obstacle is the emphasis placed by teachers on "reading" (often rote recitation) and "writing" (often copy-writing) over other critical skills such as speaking and listening, as well as the inability of teachers to support those with diverse learning needs (Dutta & Bala, 2012; Dyer, 2008).

The first study of this dissertation was an attempt to examine whether GraphoLearn English Rime, an intervention which had evidence of effectiveness among children in the UK, could be used in the Indian context. The first study forming this dissertation was an initial attempt at examining the efficacy of GraphoLearn Rime when used in the Indian context. After a short intervention period (7.5 hours across 8-weeks), Grade 3 students who played GraphoLearn showed significantly greater and faster development on the in-game measure of letter-sound knowledge as compared to students who did not play GraphoLearn. Meaningful effects of the intervention were not seen on the other in-game assessments (rime unit recognition and word recognition) or on the out-of-game assessments of word reading, pseudoword reading, and spelling.

The findings were meaningful considering that many teachers in India are known to place greater focus on the instruction of letter names than letter sounds (Gupta, 2014). Prior to the intervention, children in both the intervention and control groups were only able to accurately identify 35%, or eight, of the letter-sound correspondences presented to them in the in-game assessment. After playing GraphoLearn for about an hour per week over a period of two months, children were able to accurately identify nearly twice as many (64% or 15) of the presented letter-sound correspondences. Letter-sound knowledge has been established as a foundational skill necessary for children's understanding of the alphabetic principle (Byrne & Fielding-Barnsley, 1989). Through GraphoLearn, children were able to quickly acquire this foundational knowledge in an environment where they otherwise may not have.

Study II was designed to reevaluate the efficacy of GraphoLearn Rime to try and better understand the lack of effects beyond letter-sound knowledge seen in Study I. Changes in the study included a younger sample (Grades 1 and 2) given the greater impacts seen as a result of early intervention (National Reading Panel, 2000), as well as the use of a larger set of oral and paper-based measures which were standardized and validated for use with children in India. In addition to word reading and spelling, children were assessed on measures of phonological awareness through a rime identification task and phonemic awareness through a phoneme replacement task. The intervention was carried out with a greater number of students to improve power to detect effects and was also planned over a longer time duration. Unfortunately, contextual factors resulted in a shortened intervention duration and ultimately children received an average of six and a half hours of intervention over a period of five weeks. Students who played GraphoLearn showed significant improvement across all in-game measures (letter-sound knowledge, rime unit recognition, word recognition). Similar to what was seen in Study I, prior to the intervention, students in both groups were only able to accurately identify an average of eight letter-sound correspondences presented to them. After the intervention, those in the GraphoLearn group were able to recognize 18, or 75%, of the presented letter-sound correspondences. Effects on the rime unit and word recognition tasks were smaller but still significant. Once again, there were no significant effects on the oral and paper-based measures.

GraphoLearn, as an adaptive intervention, requires players to reach a passing criterion before allowing them to move ahead in the game. While this allows children to play and gain practice at an individual pace, this also results in variation in children's game progress at the end of an intervention. We recognized early on that some children were on track to play the game to completion within the five-week time frame, while others struggled, and never moved past the first game stream. It was important to examine these differences in children's game progress to understand how GraphoLearn could be maximally beneficial and for who. We found that children who had stronger English literacy skills prior to the intervention were, perhaps unsurprisingly, also the ones who made greater progress in GraphoLearn. We then compared the effectiveness of GraphoLearn for children with stronger versus weaker pre-existing English literacy skills. Results indicated the GraphoLearn was more effective at improving children's performance on the in-game tasks for children with stronger pre-existing literacy skills and less effective at improving performance of children with weaker pre-existing literacy skills. These findings were in line with studies conducted using GraphoLearn English Rime in the UK (Ahmed et al., 2020; Wilson et al., 2021).

Overall, both Studies I and II found evidence in support of GraphoLearn's positive impact on early reading skills. In both Study I and II, students who played GraphoLearn showed improved letter-sound knowledge. Students in Study II also showed improved rime unit and word recognition at least when skills were assessed by the game. Letter-sound knowledge is a critical foundational skill and a steppingstone towards children being able to use grapheme-phoneme correspondences for decoding (e.g., Ehri, 2020). Moreover, students were able to acquire these skills by independently playing a game for only a few hours.

What children were unable to do after GraphoLearn intervention, however, was apply their learnings from the game to the oral and paper-based tasks. Most can agree that the purpose of using ed-tech such as digital games, is not simply to help students learn the game. Rather the expectation is that students apply what they learn in a game to an out-of-game context. Transfer of learning is the ability to apply knowledge gained in one context to another context (Haskell, 2000; Singley & Anderson, 1989). For learning games, the focus is typically on ensuring that learning from the game can transfer to assessments outside of the game. Although there are many levels of transfer (see Haskell, 2000), it is most commonly classified as being either "near" or "far". Near transfer is the ability to apply learning in a context which is similar to the game, whereas far transfer is the ability to apply learning in a context which is dissimilar to the game (Bainbridge et al., 2022). Transfer generally has been found not to occur as often as perhaps expected but is something that can be facilitated both in and out of a game setting (Perkins & Saloman, 1992; Wouters & Oostendorp; 2013).

An increasing amount of research, particularly that which has focused on developing countries, has highlighted the limitations of ed-tech when used as a standalone tool (e.g., Beuermann et al., 2015). When game content is not tailored to fit exiting curriculum and when teachers are not changing their instructional practices to correspond to the methods used by the software, there is no facilitation of transfer. In both Studies I and II, the time that children played GraphoLearn was essentially the only time they received phonics-based instruction. Content of GraphoLearn was based on what had been developed for use in the UK where children already receive mandatory phonics instruction and teachers in our studies were not supported to implement phonics instruction in the classroom. The out-of-game tasks contained none of the trained content and also were assessed in a completely different modality. In GraphoLearn, children listen to a speech sound, recognize the visual form, and use their finger to make a selection. The oral measures required children to listen to a speech stream presented by the assessor and then orally produce a response. Similarly, the paper-based reading measures required children to read aloud. Although children were able to apply their skills in the game environment, they received no support to make the necessary connections between the game environment and the out-of-game assessments. Consequently, there were no effects on the out-of-game measures, even among the children who had a stronger level of pre-existing literacy skill and who were able to make significant progress in the game.

Overall, the findings were in line with other evaluations of supplementary ed-tech tools which have found positive but generally small effects on children's reading (ES= .11) (Cheung & Slavin, 2013). The findings also provide further support on the limitations of GraphoLearn and direction for future research. When not integrated as a part of a more comprehensive instructional program, GraphoLearn can help children learn subskills of reading such as letter-sound correspondences, but it alone is not enough to support decoding (McTigue et al., 2019). Of critical importance is understanding the optimal operating conditions under which GraphoLearn can be maximally beneficial. This includes investigating the amount of exposure (i.e., play time and game progress) which is required as well as investigating how teaching and learning outside of the game (i.e., classroom instruction) needs to be modified to ensure a transfer of learning to an out-of-game context.

4.3 Limitations

Although the studies composing the dissertation have strengths such as the use of rigorous randomized controlled trials to study the efficacy of GraphoLearn with multiple age groups across two cities, there are some limitations that should be considered. In both Studies I and II there were time constraints which limited the intervention duration. In Study I, children received approximately 7.5 hours of intervention over an 8-week period. In Study II, children received approximately 6.5 hours of intervention over a 5-week period. In both studies there was less intervention time than planned due to reasons which were out of our control such as weather-related school closures, school events which prevented children from attending the intervention sessions, and holidays which were not scheduled in the school calendar but resulted in student absenteeism. Nevertheless, it must be acknowledged that the short intervention duration limited children's progress in GraphoLearn. In addition, despite Studies II and III having a significantly larger sample than Study I, all of the studies had sample size limitations resulting in reduced power to detect effects.

There were also limitations regarding the measures which were used. It must be acknowledged that students in the GraphoLearn group had repeated exposure to the GraphoLearn in-game assessment tasks. The GraphoLearn assessment tasks are presented after every four streams and the game contains a total of seven assessment levels. Students who completed the game would have been exposed to the in-game assessment task a total of six times prior to post-testing. However, given that the game requires an 80% passing criterion within each stream, players will only reach the assessment levels if they are learning and progressing through the game. Thus, we do not believe that the repeated exposure to the in-game assessment tasks would have large effects on the results. Nevertheless, future research should be conducted using pre- and post-test GraphoLearn in-game assessment tasks which contain content that is different from the GraphoLearn in-game assessment tasks players are exposed to in the game. In addition, we currently do not have reliability information for the GraphoLearn in-game assessment tasks from the English version of the game. Reliability information gathered from the Finnish version of GraphoLearn has indicated that the assessments conducted through GraphoLearn have high reliability (Hautala et al., 2020). It is critical that the assessments in the English version of GraphoLearn are similarly evaluated.

Regarding the paper and pencil measures, a limitation in both Studies I and II was that students were unfamiliar with some of the tasks and could have found them to be difficult. In Study I we used tasks which were normed for children in the United Kingdom who are native speakers of English and/or have much more exposure to English than the children that were in our sample. In Study II, we selected tasks which were normed for children in India, however, the tasks were not the types of tasks students were typically exposed to in their classrooms. The tasks also differed from what children had practiced in GraphoLearn since they required oral production whereas GraphoLearn simply required recognition. In future studies it would be worthwhile to develop a set of experimental measures to also assess skills in a manner similar to the game. A related limitation that emerged in Study III was the lack of matching phonological awareness tasks to assess skills in both languages at all grain sizes. There were Hindi tasks which assessed phonological awareness at the rhyme and syllable level, but not at the phoneme level. On the contrary, there were English tasks which assessed phonological awareness at the rhyme and phoneme level, but not at the syllable level. Having equivalent tasks in both languages could have helped to provide more specific information on cross-language transfer. Furthermore, although we assessed a wide range of literacy skills, we did not assess children's oral vocabulary skill which prevented us from taking children's pre-existing language ability into consideration across the three studies. Future studies must ensure that oral vocabulary is carefully assessed.

An additional limitation specific to Study III, was the use of cross-sectional data and correlational analyses which limits the conclusions we are able to draw from the findings. It is important that a greater number of longitudinal studies be conducted in India to understand children's literacy development over time. There is also a need for an increased number of rigorous RCT's to better understand effective instructional methods for children's phonological awareness and reading development. Finally, it is important to acknowledge that these studies examined a very small and specific sample of students. Given the great amount of diversity in India, we are limited in our ability to generalize these findings to all Grade 1-3 students who are studying in English-medium schools across the country. It is of the utmost importance that researchers continue examining literacy development and intervention in different schools, cities, and states across the country.

4.4 Practical Implications and Future Recommendations

Findings from this dissertation add to a generally sparse research-base on children's literacy development in India, particularly concerning children who are attending English-medium schools upon school entry. A new National Education Policy aims to address many of the factors which contribute to India's learning crisis, including the recognition of foundational literacy and numeracy as the highest priority of the education system (Ministry of Human Resource Development, 2020). These policy changes coupled with a steady infusion of investment directed toward the use of ed-tech in K-12 settings offer rich potential in the utilization of digital supports to supplement early literacy skill development. Yet there remains a continued need to understand how policy can be implemented in a way which is effective for *all.*

4.4.1 Foundational Literacy as the Highest Priority of the Education System

Despite policy recognition of the importance of building phonological skills for foundational reading, recommendations have been made for the use of a balanced approach to literacy. Teachers have been told to "follow what is appropriate for their classroom and where every child learns in a joyful and stress-free manner by taking the best of multiple approaches" (Ministry of Education, 2021, p. 65). At least in the case of English, balanced literacy has been widely critiqued by reading researchers for being a renamed version of the whole-language approach (Moats, 2000), in which phonics and other ideas of how children learn to read are mixed in (Hanford, 2019). In other contexts, this has been found to result in phonics instruction which is neither explicit nor systematic (Snow, 2017), despite the fact that explicit and systematic phonics is known to be one of the most effective ways to teach children foundational literacy skills in English (National Reading Panel, 2000), and has also been found effective in the Indian context (e.g., Dixon et al., 2011). Proponents of balanced literacy criticize phonics for being an unbalanced approach to reading instruction given the many components involved in reading. While it is important to acknowledge that the ultimate goal is for children to be able to read with understanding, decoding remains a necessary component of reading comprehension (see Simple View of Reading, Gough & Tunmer, 1986). Thus, proponents of the phonics approach have emphasized a need to focus on developing skills as and when they are most developmentally appropriate (Castles et al., 2018). For the development of early reading, at least in English, the most appropriate method is phonics.

A lack of clear guidance in the National Education Policy on English learners may be intentional given that policymakers have pushed for education in the native language until at least Grade 5. The debate on whether children should be educated in India's vernacular languages versus in English has been argued for decades and was most recently triggered by the National Education Policy. In terms of literacy, the debate is an important one to have. There is a wealth of research supporting the fact that it is easier for children to learn to read in a language which they can speak and understand. Once children develop reading skills in the L1, they are able to utilize shared skills when learning to read in an L2 (Koda 2008). Researchers who have examined English literacy acquisition among students in India have warned against the early introduction of English, or before children reach a threshold level of literacy in their L1 which can then facilitate L2 learning (Nakamura et al., 2019). Unfortunately, about 20% of students were found to have not reached this threshold even by Grade 5 (Nakamura et al., 2019). Others have recommended late-exit bilingual programs where students are instructed in their L1 for 100% of the time in kindergarten, after which use of the L1 is slowly reduced until children are instructed 100% of the time in English by Grade 5 (Shenoy et al., 2020). These recommendations, including those made in the National Education Policy, have remained as recommendations and it has become evident that many state governments will not be paying heed. For example, Telangana, a state in southeast India, announced that English-medium would be compulsory in all government schools across the state starting in the 2022–2023 school year (Apparasu, 2022).

India's attempt at reaching universal foundational literacy will be futile if the millions of children attending English-medium schools, and particularly English-medium government schools, are ignored. Rather than debating whether or not children should be taught English upon school entry, it is perhaps important to shift the conversation to how to better support these children. Findings from this dissertation reaffirm the critical contributions of foundational skills, particularly phonemic awareness, as a predictor of children's decoding skills. In light of this, and former studies which have confirmed the efficacy of phonics-based instruction which targets the development of these skills, there is a need in India for a clear recommendation for the use of phonics in place of balanced literacy in English-medium schools.

4.4.2 Teachers as the Heart of the Learning Process

The importance of teachers in the teaching and learning process has been reiterated at the national level. As a result, teachers who instruct early grades are to be "trained for the implementation of foundational literacy and numeracy as per the National Education Policy 2020 perspectives" (Ministry of Education, 2021, p. 159). For teachers in English-medium schools, this should include training on phonemic awareness and phonics instruction. Teacher knowledge is critical to students' literacy achievement (Moats, 2009). Yet, even in English-speaking countries in the Western world, many teachers lack an understanding of how to teach foundational literacy skills in a manner which is aligned to the science of reading development (e.g., Pittman et al., 2020; Washburn et al., 2016). Research has found that targeted and ongoing teacher training and preparation programs can be effective at improving teachers' understanding of reading instruction and specifically, phonological awareness, phonics, and morphological awareness (Hudson et al., 2021).

Effective phonics instruction is not only systematic but also explicit, involving clear explanations, modeling, guided practice, and frequent feedback (Piasta & Hudson, 2022). Researchers have stressed the importance of phonics going beyond the "skill and drill" of grapheme-phoneme correspondences. Rather, children need to be engaged in reflecting on these correspondences and orthographic patterns in words, as well as analyzing how words sound, are spelled, and what they mean (Piasta & Hudson, 2022; see also Adams, 2001). In addition, English learners have been found to greatly benefit from increased oral language and vocabulary support (see Goldenberg, 2020 for a discussion) and there are ways that children's L1 can be leveraged as they are learning English. It is important that both decision-makers and teachers recognize the existing gaps in teacher knowledge in India and work to improve both pre-service and in-service teacher training on literacy instruction which is aligned to research.

As teacher's work towards providing children with more comprehensive literacy instruction, an opportunity is created to integrate ed-tech tools like GraphoLearn with greater efficacy. Studies on the efficacy of GraphoLearn which have resulted in the largest effects have consistently been those in which GraphoLearn is used as a part of comprehensive teacher instruction (e.g., Saine et al., 2011), reinforcing GraphoLearn as a supplement to rather than a replacement for instruction (Kyle et al., 2013; Richardson & Lyytinen, 2014). In Finland, Saine et al. (2011) used GraphoLearn as a part of small group-remedial intervention in which students practiced prereading skills (i.e., phonological awareness and grapheme-phoneme correspondences), word segmentation, decoding, spelling, and vocabulary with a teacher. Those in the control group practiced all of the skills with the teacher whereas those in the intervention group played GraphoLearn in place of the pre-reading skills segment of the session. Integrating GraphoLearn into the remedial intervention program was found to result in greater improvements on literacy outcomes as compared to when GraphoLearn was not a part of the program.

There is strong evidence in favor of using GraphoLearn to teach pre-reading skills such as grapheme-phoneme correspondences. In India, GraphoLearn is perhaps a particularly good way to have children learn these correspondences since they are able to hear the correct pronunciations of letter-sounds, can practice as needed, and are able to receive immediate and consistent feedback; something that would be nearly impossible for a teacher to provide for each individual child in a classroom. Beyond this, teachers would need to provide explicit literacy instruction as discussed above. Instruction in which ed-tech is integrated also supports transfer; children are able to build the connections between what is being learned in the game and how they can apply that to reading words in a book with their teacher.

Generally, there is a need for increased research to understand the types of supports teachers in India would need to improve their reading instruction as well as their ability to integrate ed-tech into instruction. Despite a national push towards the increased use of ed-tech in schools inadequate teacher training, support, and monitoring has repeatedly been emphasized as critical for sustainable usage of ed-tech in schools (Sampson et al., 2019). An interesting area of exploration would be whether technology-based tools, like GraphoLearn, can be used to support teachers in developing their own knowledge of grapheme-phoneme-correspondences and how such a tool may impact their instructional methods. In an earlier mentioned study examining the efficacy of GraphoLearn ciNyanja, it was found that the intervention resulted in the greatest effects when teachers were provided with comprehensive information on the importance of letter-sound knowledge and when teachers played GraphoLearn in addition to their students, as it allowed teachers to improve their knowledge (Jere-Folotiya et al., 2014). One step forward may also be to provide teachers with scripted lessons that they could use for phonics instruction which would align with GraphoLearn to facilitate greater transfer in student learning.

4.4.3 The Extensive Use of Technology in Teaching and Learning

In 2017, the Indian government pioneered the development of the Digital Infrastructure for Knowledge Sharing (DIKSHA) platform, a national repository of digital learning material. (Ministry of Education, 2021). To make increased use of DIKSHA, decision makers have asked every state to ensure that technology is accessible across all schools. There is no doubt that ed-tech can play a meaningful role in children's learning experiences. Yet, it is important to recognize that technology is not a panacea. In many countries there remains a lack of clarity on the interactions between teachers, students, and educational content, and the role that ed-tech can and cannot play across those interactions (Ganimian et al., 2021). Particularly, teachers are often left out of the conversation despite the fact that it is ultimately teachers who control the implementation of technology and as a result, affect students' experiences (Miglani and Burch, 2019). It is critical that decision makers think deeply about the educational scenario in India and how various ed-tech tools can make meaningful contributions to teacher and/or student learning given those scenarios (see Ganimian et al., 2021 for a set of guidelines).

There is also a very clear and urgent need to critically evaluate the efficacy of various ed-tech interventions in the context of India. To date, the focus has largely been on investing and scaling digital tools with very little focus placed on ensuring their efficacy. The DIKSHA platform is estimated to be accessed by 30 million individuals daily, and yet it has never been evaluated for quality (Sharma, 2021). It is perhaps not surprising then that the increased spread of ed-tech has not resulted in large and sustained gains in student learning. It is our responsibility as researchers, tech-developers, teachers, and decisions makers to ensure we are providing children with quality tools for learning. To this end, there is a need for stakeholders to work together to conduct high-quality experimental evaluations of ed-tech tools before they are scaled.

Finally, just as teaching cannot follow a "one size fits all" approach, neither can ed-tech. From a product perspective, it is important not only to think about how implementation can be modified to fit an ed-tech tool, but also whether the tool itself needs to be modified to support implementation. In the case of GraphoLearn English Rime in India, there were clear limitations in the tool itself, particularly given that it was designed for use with students in the UK where phonics instruction is mandatory. For use in countries like India, it may be worthwhile to modify aspects of GraphoLearn. An important modification would be the inclusion of more explicit teaching of phonics in the game. This could potentially be done by adding instructional videos into the game to teach the content before students practice in a level. Given the contributions made by children's L1 in L2 literacy learning, another modification could be the inclusion of Hindi Akshara in addition to English letters to enable children to make connections between their existing knowledge of Hindi and the graphemes and phonemes they are learning in English. It is also important that ed-tech tools are developed keeping in mind resource strains present in many developing countries. In 2021, only 19% of schools in India had active internet connections (UNESCO New Delhi, 2021). It would be important to ensure that GraphoLearn is available offline so that it is accessible to all.

4.5 Concluding Remarks

This dissertation focused on the evaluation GraphoLearn English Rime for supporting the development of foundational literacy skills of children attending English-medium government schools in India. Overall, the results indicated that GraphoLearn was effective at improving children's knowledge of grapheme-phoneme correspondences, particularly letter-sounds. Results also highlighted the limitations of ed-tech tools, such as GraphoLearn, particularly when they are implemented in the absence of comprehensive literacy instruction. An examination of phonological predictors of children's literacy skills confirmed the importance of English phonological awareness skills, particularly phonemic awareness, to decoding. Findings also provided insight in the contributions made by children's L1 in their L2 literacy learning. Taken together, there is evidence for the use of phonics-based literacy instruction for children who are attending English-medium schools in India. However, there is a significant need for greater research to understand how phonics-based instruction can be implemented in English-medium classrooms across India and the role that ed-tech can play to augment learning in these environments with the goal of reducing learning poverty across the country.

SUMMARY IN FINNISH

Intiassa, jossa on yksi maailman suurimmista koulutusjärjestelmistä, on myös paljon oppimisköyhyyttä (World Bank Group, 2019b). Oppimisköyhyyden syiksi on tunnistettu puutteelliset kotioppimisympäristöt, riittämättömät kouluvalmiudet, vanhanaikaiset opetusmenetelmät, huonosti koulutetut opettajat, liian kunnianhimoiset opetussuunnitelma-odotukset sekä oppimisvaikeuksien varhaisen tunnistamisen ja erityisen tuen puute (Banerji, 2018). Intian korkea monikielisyys vaikeuttaa entisestään oppimiskriisin ratkaisemiseen liittyviä haasteita. Englantia pidetään mahdollisuuksien kielenä, ja sillä on jatkuvasti kasvava rooli intialaisessa yhteiskunnassa. Vanhemmat ilmoittavat lapsensa englanninkielisiin kouluihin toivoen voivansa tarjota lapsilleen paremman tulevaisuuden. Monet englanninkieliset koulut eivät kuitenkaan pysty tarjoamaan lapsille korkealaatuista opetus- ja oppimiskokemusta (Dutta & Bala, 2012). Valtakunnallinen tutkimus vuodelta 2016 osoitti, että vain 32 % kolmasluokkalaisista osasi lukea yksinkertaisia sanoja englanniksi (ASER Centre, 2016).

Toisin kuin puhuttu kieli, jonka lapsi tyypillisesti oppii kielelle altistuessaan, lukeminen on erittäin monimutkainen taito, joka vaatii selkeää opetusta ja harjoittelua. Lukutaidon perusta on kyky yhdistää puhutun kielen äänteet niitä vastaavaan kirjoitettuun merkkiin. Englannissa äänteet (foneemit) esitetään kirjaimilla tai useamman kirjaimen yhdistelmillä (grafeemit). Lukemaan oppiminen edellyttää ymmärrystä siitä, kuinka grafeemit edustavat foneemia (Castles et al., 2018). Tämän ymmärryksen perustana ovat kirjainten tuntemus ja fonologinen tietoisuus. Kirjainten tuntemus sisältää ymmärryksen kirjaimen nimestä, muodosta ja äänestä (Ehri, 2020). Fonologinen tietoisuus määritellään kyvyksi tunnistaa ja manipuloida puheäänten eri yksiköitä, kuten tavuja ja foneemeja puhutussa kielessä (Piasta & Hudson, 2022).

Lukemisen kehitys on erityisen monimutkaista kun lapset oppivat puhumaan ja lukemaan kieltä yhtä aikaa. Tämä on yleinen tilanne lukemaan oppivilla lapsilla Intiassa. Äidinkielen (L1) ja toisen kielen (L2) suhdetta lukemaan oppimisessa tarkastelleet aiemmat tutkimukset ovat osoittaneet, että fonologinen tietoisuus on itse asiassa kaksisuuntaista, ja yhden kielen taidot helpottavat toisen lukemista (Gottardo et al., 2021). Tehokkain lukemaan opettamisen menetelmä on sellainen, joka opettaa grafeemien ja foneemien välisiä suhteita lapselle systemaattisesti (esim. National Reading Panel, 2000). Se sopii parhaiten jopa lapsille, jotka opiskelevat englantia toisena kielenä (Goldenberg, 2020). Systemaattinen foneemien ja grafeemien opetus ei ole kuitenkaan laajalti käytetty opetusmenetelmä Intiassa.

Monissa matala- ja keskituloisissa maissa, jotka kamppailevat huonojen oppimistuloksien kanssa, koulutusteknologiaa pidetään lupaavana vaihtoehtona. Tutkimus koulutusteknologian interventioiden tehokkuudesta näissä konteksteissa on kuitenkin edelleen hyvin rajallista. Tämän väitöskirjan yleisenä tavoitteena olikin lisätä rajallista olemassa olevaa tutkimusta, joka keskittyy lukemaan oppimiseen Intian englanninkielisissä kouluissa. Tarkemmin sanottuna tässä väitöskirjassa tarkastellaan GraphoLearn English Rimen, tietokoneavusteisen intervention tehokkuutta englannin perusoppimisen tukemiseen kolmen tutkimuksen sarjassa.

Kahdessa ensimmäisessä tutkimuksessa GraphoLearn English Rimen tehokkuutta arvioitiin satunnaistetulla kontrolloidulla koeasetelmalla. Näiden tutkimusten osallistujat olivat 1–3-luokkalaisia lapsia, jotka kävivät englanninkielisiä valtion kouluja kahdessa Intian kaupungissa. Suurin osa lapsista opiskeli englantia toisena tai kolmantena kielenä ja tuli kodeista, joissa englantia ei käytetty usein. Interventioryhmään nimetyt lapset pelasivat GraphoLearnia kuulokkeilla varustetulla kosketusnäyttölaitteella. Vertailuryhmään sijoitetut lapset pelasivat samanlaisilla laitteilla matematiikkapeliä. Molemmat ryhmät pelasivat omia pelejään koulupäivän aikana. Lasten taitoja, muun muassa peruslukutaitoa ja fonologisia taitoja arvioitiin ennen ja jälkeen intervention. Tutkimuksessa II lapsia arvioitiin ennen interventiota myös hindin-kielisillä taitotesteillä, jotka suurimmalle osalle lapsista oli heidän äidinkielensä. Tutkimuksessa III tutkittiin lasten lukutaidon fonologisia ennustajia molemmilla kielellä ja niiden välillä, jotta ymmärrettäisiin paremmin miten lukutaito ja siihen liittyvät perustaidot siirtyvät kielestä toiseen.

Sekä tutkimusten I että II havainnot osoittivat, että GraphoLearnia pelanneet lapset kehittyivät paremmin niissä tehtävissä, jotka tehtiin tietokoneavusteisesti kuin matematiikkapeliä pelanneet kontrolliryhmän lapset. Ryhmien väliset erot olivat tilastollisesti merkitseviä kirjainten tuntemuksessa, riimien tunnistamisessa ja sanantunnistuksessa. Ryhmien välillä ei kuitenkaan ollut merkittäviä eroja kynä-paperi -tehtävissä, mikä viittaa siihen, että oppiminen ei siirtynyt pelin ulkopuolisiin tehtäviin. Tutkimuksessa II havaittiin, että GraphoLearn interventiolla oli suurempi vaikutus lapsilla, joilla oli vahvempi englannin kielen taito. Interventiolla ei kuitenkaan ollut vaikutusta kynä-paperi -tehtäviin edes niillä lapsilla, joilla oli vahvempi englannin kielen taito. Tutkimuksessa III otimme askeleen taaksepäin tutkiaksemme lasten lukutaitoa ja fonologista taitoa äidinkielellä (L1) ja toisella kielellä (L2). Tämän tutkimuksen tarkoitus oli ymmärtää paremmin äidinkielen taidon merkitystä toisen kielen oppimiseen. Tulokset osoittivat, että kunkin kielen fonologiset taidot ennakoivat lukutaitoa kyseisellä kielellä, mikä tukee aiempia tuloksia fonologisen tietoisuuden kriittisestä roolista lukemisessa. Tulokset osoittivat myös, että hindin (L1) fonologiset taidot ennustivat englanninkielisten sanojen lukemista (L2).

Kaiken kaikkiaan sekä tutkimuksissa I että II löydettiin todisteita GraphoLearnin myönteisestä vaikutuksesta varhaiseen lukutaitoon. Sekä tutkimuksessa I että II GraphoLearnia pelanneilla lapsilla kirjainten ja äänteiden tuntemus parani. Tutkimuksessa II myös riimien ja sanojen tunnistaminen parani. Kirjainten ja äänteiden vastaavuuden osaaminen on lukutaidon välttämätön perustaito (esim. Ehri, 2020). On huomattava, että lapset oppivat kirjain-äänne vastaavuuksia pelin avulla vaikka interventio kesti yhteensä vain muutaman tunnin ajan. Tulokset korostavat kuitenkin myös tietokonepohjaisten interventioiden rajoitteita, koska vaikutusta ei havaittu kynä-paperi -tehtäviin. Jatkotutkimuksissa onkin pyrittävä ymmärtämään paremmin niitä olosuhteita, joissa GraphoLearnin kaltaiset interventiot voivat olla tehokkaampia. Tämä sisältää vaaditun altistumisen määrän (eli peliajan ja pelin edistymisen) sekä sen tutkimisen, kuinka luokkahuoneopetusta on muutettava, jotta voidaan varmistaa oppimisen siirtyminen pelin ulkopuolelle. Tutkimuksen III havainnot osoittavat, että lasten olemassa olevaa L1-taitoa voidaan mahdollisesti hyödyntää paremmin lukutaidon opetuksessa englanninkielisissä luokkahuoneissa.

Kaiken kaikkiaan on olemassa tutkimusnäyttöä siitä, että kirjainten ja äänteiden vastaavuuden opettamiseen perustuva lukutaidon opetus on tehokasta lapsille, jotka käyvät englanninkielisiä kouluja Intiassa. Tarvitaan kuitenkin vielä merkittävästi lisää tutkimusta, jotta ymmärrämme miten tällaista opetusta voitaisiin toteuttaa tehokkaasti englanninkielisissä luokkahuoneissa kaikkialla Intiassa ja mikä rooli tietokoneavusteisilla tekniikoilla voi olla oppimisen lisäämisessä ja oppimisköyhyyden vähentämisessä näissä ympäristöissä.

REFERENCES

Adams, M. J. (2001). Alphabetic anxiety and explicit, systematic phonics instruction: A cognitive science perspective. In S. B. Neuman & D. K. Dickinson (Eds.), *Handbook of early literacy research* (pp. 66–80). Guilford Press.

Ahmed, H., Wilson, A. M., Mead, N., Noble, H., Richardson, U., Wolpert, M. A., & Goswami, U. (2020). An evaluation of the efficacy of GraphoGame rime for promoting English phonics knowledge in poor readers. *Frontiers in Psychology*, *5*(132), 1– 12. https://doi.org/10.3389/feduc.2020.00132

Ali, M. (2022, January 21). English medium worries to teacher post aspirants in Telangana. *The New Indian Express.* https://www.newindianexpress.com/states/telangana/2022/jan/21/english-medium-worries-for-teacher-post-aspirants-in-telangana-2409402.html

Anthony, J. L., & Lonigan, C. J. (2004). The nature of phonological awareness: Converging evidence from four studies of preschool and early grade school children. *Journal of Educational Psychology, 96*(1), 43-55. https://doi.org/10.1037/0022-0663.96.1.43

Apel, K. (2014). A comprehensive definition of morphological awareness: Implications for assessment. *Topics in Language Disorders*, *34*(3), 197-209. https://doi.org/10.1097/TLD.0000000000000019

Apparasu, S. R. (2022, January 18). Telangana cabinate decides to make English midum compulsory in all govt schools from coming academic year. *Hindustan Times.* https://www.hindustantimes.com/india-news/telangana-cabinet-decides-to-make-english-medium-compulsory-in-all-govt-schools-from-coming-academic-year-101642444781386.html

ASER Centre. (2016). *Annual status of education report (rural) 2016.* https://img.asercentre.org/docs/Publications/ASER%20Reports/ASER%202016/aser_2016.pdf

ASER Centre. (2018). *Annual status of education report (rural) 2018.* http://img.asercentre.org/docs/ASER%202018/Release%20Material/aserreport2018.pdf

August, D., McCardle, P., & Shanahan, T. (2014). Developing literacy in English language learners: Findings from a review of the experimental research. *School Psychology Review*, *43*(4), 490-498. https://doi.org/10.1080/02796015.2014.12087417

August, D., & Shanahan, T. (2006). *Developing literacy in second-language learners: Report of the national literacy panel on language minority children and youth.* Lawrence Erlbaum Associates.

Azam, M., Chin, A., & Prakash, N. (2013). The returns to English-language skills in India. *Economic Development and Cultural Change, 61*(2), 335-367. https://doi.org/10.1086/668277

Bainbridge, K., Shute, V., Rahimi, S., Liu, Z., Slater, S., Baker, R. S., & D'Mello, S. K. (2022). Does embedding learning supports enhance transfer during

game-based learning?. *Learning and Instruction, 77*, 101547. https://doi.org/10.1016/j.learninstruc.2021.101547
Banerjee, A., Cole, S., Duflo, E., & Linden, L. (2007). Remedying education: Evidence from two randomized experiments in India. *The Quarterly Journal of Economics, 122*(3), 1235–1264. https://doi.org/10.1162/qjec.122.3.1235
Banerji, R. (2018). Behind the headlines. In *Annual status of education report (rural) 2018* (pp. 13–16). ASER Centre. http://img.asercentre.org/docs/ASER%202018/Release%20Material/aserreport2018.pdf
Beuermann, D. W., Cristia, J., Cueto, S., Malamud, O., & Cruz-Aguayo, Y. (2015). One Laptop per Child at home: Short-term impacts from a randomized experiment in Peru. *American Economic Journal: Applied Economics, 7*(2), 53-80. https://doi.org/10.1257/app.20130267
Branum-Martin, L., Tao, S., & Garnaat, S. (2015). Bilingual phonological awareness: Reexamining the evidence for relations within and across languages. *Journal of Educational Psychology, 107*(1), 111–125. https://doi.org/10.1037/a0037149
Branum-Martin, L., Tao, S., Garnaat, S., Bunta, F., & Francis, D. J. (2012). Meta-analysis of bilingual phonological awareness: Language, age, and psycholinguistic grain size. *Journal of Educational Psychology, 104*(4), 932–944. https://doi.org/10.1037/a0027755
Byrne, B., & Fielding-Barnsley, R. (1989). Phonemic awareness and letter knowledge in the child's acquisition of the alphabetic principle. *Journal of Educational Psychology, 81*(3), 313–321. https://doi.org/10.1037/0022-0663.81.3.313
Castles, A., Rastle, K., & Nation, K. (2018). Ending the Reading wars: Reading acquisition from novice to expert. *Psychological Science in the Public Interest*, *19*(1), 5–51. https://doi.org/10.1177/1529100618772271
Census of India. (2011a). *Population by bilingualism, trilingualism, age and sex, India*. https://censusindia.gov.in/nada/index.php/catalog/43470
Census of India. (2011b). *Population by mother tongue, India.* https://censusindia.gov.in/nada/index.php/catalog/10191
Central Square Foundation. (2015). *The EdTech promise: Catalysing quality school education at scale.* http://www.centralsquarefoundation.org/wpcontent/uploads/2015/11/The-EdTech-Promise-Catalysing-Quality-SchoolEducation-at-Scale.pdf
Central Square Foundation. (2020). *State of the sector report on private schools in India.* https://centralsquarefoundation.org/State-of-the-Sector-Report-on-Private-Schools-in-India.pdf
Chall, J. S. (1967). *Learning to read: The great debate.* McGraw Hill.
Cherodath, S., & Singh, N. C. (2015). The influence of orthographic depth on reading networks in simultaneous biliterate children. *Brain and Language, 143*, 42–51. https://doi.org/10.1016/j.bandl.2015.02.001

Cheung, A. C., & Slavin, R. E. (2013). Effects of educational technology applications on reading outcomes for struggling readers: A best-evidence synthesis. *Reading Research Quarterly*, *48*(3), 277–299. https://doi.org/10.1002/rrq.50

Cristia, J., Ibarrarán, P., Cueto, S., Santiago, A., & Severín, E. (2017). Technology and child development: Evidence from the One Laptop per Child program. *American Economic Journal: Applied Economics, 9*(3), 295–320. https://doi.org/10.1257/app.20150385

Cummins, J. (1979). Linguistic interdependence and the educational development of bilingual children. *Review of Educational Research*, *49*(2), 222–251. https://doi.org/10.2307/1169960

Datta, S., & Kingdon, G. (2021). *The myth and reality of teacher shortage in India: An investigation using 2019-2020 data.* RISE Working Paper Series 21/072. https://doi.org/10.35489/BSG-RISE-WP_2021/072

Dixon, P., Schagen, I., & Seedhouse, P. (2011). The impact of an intervention on children's reading and spelling ability in low-income schools in India. *School Effectiveness and School Improvement*, *22*(4), 461–482. https://doi.org/10.1080/09243453.2011.625125

Duflo, E., Hanna, R., & Ryan, S. P. (2012). Incentives work: Getting teachers to come to school. *American Economic Review*, *102*(4), 1241–1278. https://doi.org/10.1257/aer.102.4.1241

Dutta, U., & Bala, N. (2012). *Teaching of English at primary level in government schools*. National Council of Education Research and Training. http://www.ncert.nic.in/departments/nie/del/publication/pdf/English_Primary_level.pdf

Dyer, C. (2008). Early years literacy in Indian urban schools: Structural, social and pedagogical issues. *Language and Education*, *22*(5), 237–253. https://doi.org/10.1080/09500780802152630

Ehri, L. C. (2003). *Systematic phonics instruction: Findings of the National Reading Panel*. http://www.standards.dfes.gov.uk/pdf/literacy/lehri_phonics.pdf.

Ehri, L. C. (2020). The science of learning to read words: A case for systematic phonics instruction. *Reading Research Quarterly, 55*, S45–S60. https://doi.org/10.1002/rrq.334

Ehri, L. C., & Wilce, L. S. (1983). Development of word identification speed in skilled and less skilled beginning readers. *Journal of Educational Psychology, 75*(1), 3–18. https://doi.org/10.1037/0022-0663.75.1.3

Ehri, L. C., & Wilce, L. S. (1985). Movement into reading: Is the first stage of printed word learning visual or phonetic?. *Reading Research Quarterly*, *20*(2), 163–179. https://doi.org/10.2307/747753

Elliot, C. D., Smith, P., & McCulloch, K. (1996). *British Ability Scales II (BAS II).* NFER-NELSON.

February, P. (2018). *Teaching and learning to read in Afrikaans: teacher competence and computer-assisted support* [Doctoral dissertation, University of

Jyväskylä]. JYX Digital Repository. https://jyx.jyu.fi/handle/123456789/59086

Foorman, B., Beyler, N., Borradaile, K., Coyne, M., Denton, C. A., Dimino, J., Furgeson, J., Hayes, L., Henke, J., Justice, L., Keating, B., Lewis, W., Sattar, S., Streke, A., Wagner, R., & Wissel, S. (2016). *Foundational skills to support reading for understanding in kindergarten through 3rd grade*. National Center for Education Evaluation and Regional Assistance (NCEE), Institute of Education Sciences, U.S. Department of Education. https://ies.ed.gov/ncee/wwc/Docs/practiceGuide/wwc_foundationalreading_040717.pdf

Ganimian, A. J., Hess, F. M., & Vegas, E. (2020). *Realizing the promise: How can education technology improve learning for all.* Brookings Institution. https://www.brookings.edu/essay/realizing-the-promise-how-can-education-technology-improve-learning-for-all/

Genesee, F., Geva, E., Dressler, D., & Kamil, M. (2006). Synthesis: Cross-linguistic relationships. In D. August & T. Shanahan (Eds.), *Developing literacy in second-language learners: A report of the National Literacy Panel on Language-Minority Children and Youth* (pp. 153–174). Erlbaum.

Goldenberg, C. (2020). Reading wars, reading science, and English learners. *Reading Research Quarterly*, *55*(S1), S131–S144. https://doi.org/10.1002/rrq.340

Goodman, K. S. (1967). Reading: A psycholinguistic guessing game. *Journal of the Reading Specialist, 6*(4), 126–135. https://doi.org/10.1080/19388076709556976

Goswami, U. (2002). In the beginning was the rhyme? A reflection on Hulme, Hatcher, Nation, Brown, Adams & Stuart. *Journal of Experimental Child Psychology, 82*, 47–57. https://doi.org/10.1006/jecp.2002.2673

Goswami, U. & Bryant, P.E. (1990). *Phonological skills and learning to read.* Lawrence Erlbaum.

Gottardo, A., Chen, X., & Huo, M. R. Y. (2021). Understanding within-and cross-language relations among language, preliteracy skills, and word reading in bilingual learners: Evidence from the science of reading. *Reading Research Quarterly, 56*(S1), S371–S390. https://doi.org/10.1002/rrq.410

Gough, P.B., & Tunmer, W.E. (1986). Decoding, reading, and reading disability. *Remedial and Special Education, 7*(1), 6–10. https://doi.org/10.1177/074193258600700104

Graddol, D. (2010). *English next India*. British Council. https://www.teachingenglish.org.uk/sites/teacheng/files/english-next-india-2010-book.pdf

Gupta, R. (2014). Change in teaching practices: Case of phonics instruction in India. *Procedia-Social and Behavioral Sciences, 116*, 3911–3915. https://doi.org/10.1016/j.sbspro.2014.01.865

Hanford, E. (2019). At a loss for words. *APM Reports.* https://www.apmreports.org/episode/2019/08/22/whats-wrong-how-schools-teach-reading

Haskell, R. E. (2000). *Transfer of learning: Cognition and instruction*. Elsevier.
Hautala, J., Heikkilä, R., Nieminen, L., Rantanen, V., Latvala, J. M., & Richardson, U. (2020). Identification of reading difficulties by a digital game-based assessment technology. *Journal of Educational Computing Research, 58*(5), 1003–1028. https://doi.org/10.1177/0735633120905309
Heikkilä., R., Aro, M., N.rhi, V., Westerholm, J., & Ahonen, T. (2013). Does training in syllable recognition improve reading speed? A computer-based trial with poor readers from second and third grade. *Scientific Studies of Reading, 17*(6), 398–414. https://doi.org/10.1080/10888438.2012.753452
Hintikka, S., Aro, M., & Lyytinen, H. (2005). Computerized training of the correspondences between phonological and orthographic units. *Written Language and Literacy, 8*(2), 79–102. https://doi.org/10.1075/wll.8.2.07hin
Hudson, A. K., Moore, K. A., Han, B., Wee Koh, P., Binks-Cantrell, E., & Malatesha Joshi, R. (2021). Elementary teachers' knowledge of foundational literacy skills: A critical piece of the puzzle in the science of reading. *Reading Research Quarterly*, *56*(S1), S287–S315. https://doi.org/10.1002/rrq.408
Hulme, C., Hatcher, P. J., Nation, K., Brown, A., Adams, J., & Stuart, G. (2002). Phoneme awareness is a better predictor of early reading skill than onset-rime awareness. *Journal of Experimental Child Psychology*, *82*(1), 2–28. https://doi.org/10.1006/jecp.2002.2670
India Brand Equity Foundation. (2021, November 26). India to become the edtech capital of the world. *India Brand Equity Foundation.* https://www.ibef.org/blogs/india-to-become-the-edtech-capital-of-the-world
Jere-Folotiya, J., Chansa-Kabali, T., Munachaka, J.C., Sampa, F., Yalukanda, C., Westerholm, J., & Lyytinen, H. (2014). The effect of using a mobile literacy game to improve literacy levels of grade one students in Zambian schools. *Educational Technology Research and Development, 62*(4), 417–436. https://doi.org/10.1007/s11423-014-9342-9
Joshi, R. M., Nakamura, P. R., & Singh, N. C. (2017). Reading research and practice: Indian perspective. *New Directions for Child and Adolescent Development*, *2017*(158), 43–53. https://doi.org/10.1002/cad.20222
Khan, M., & Khan, R. (2021). Phonological Awareness and phonics instruction: Inclusive practice that benefits all kinds of learners. *Asia Pacific Journal of Developmental Differences*, *8*(1), 173–185. https://doi.org/10.3850/S2345734121000076
Kirby, J. R., Deacon, S. H., Bowers, P. N., Izenberg, L., Wade-Woolley, L., & Parrila, R. (2012). Children's morphological awareness and reading ability. *Reading and Writing*, *25*(2), 389–410. https://doi.org/10.1007/s11145-010-9276-5
Koda, K. (2008). Impacts of prior literacy experience on second language learning to read. In K. Koda & A. M. Zehler (Eds.), *Learning to read across languages: Cross-linguistic relationships in first- and second language literacy development* (pp. 68–96). Routledge.

Kurrien, J. (2005). *Notes for the meeting of the national focus group on teaching of English and note on introduction of English at the primary stage.* Ms., NFG-English. National Council of Education Research and Training.

Kyle, F., Kujala, J., Richardson, U., Lyytinen, H., & Goswami, U. (2013). Assessing the effectiveness of two theoretically motivated computer-assisted reading interventions in the United Kingdom: GG rime and GG phoneme. *Reading Research Quarterly*, *48*(1), 61–76. https://doi.org/10.1002/rrq.038

Levin, I., & Ehri, L. C. (2009). Young children's ability to read and spell their own and classmates' names: The role of letter knowledge. *Scientific Studies of Reading, 13*(3), 249–273. https://doi.org/10.1080/10888430902851422

Lloyd, S. (1992). *The phonics handbook: A handbook for teaching reading, writing and spelling (Jolly Phonics)*. Jolly Learning.

Lyytinen, H., Erskine, J., Kujala, J., Ojanen, E., & Richardson, U. (2009). In search of a science-based application: A learning tool for reading acquisition. *Scandinavian Journal of Psychology, 50*(6), 668–675. https://doi.org/10.1111/j.1467-9450.2009.00791.x

Major, L., Francis, G. A., & Tsapali, M. (2021). The effectiveness of technology-supported personalised learning in low- and middle-income countries: A meta-analysis. *British Journal of Educational Technology*, *52*(5), 1935–1964. https://doi.org/10.1111/bjet.13116

Masonheimer, P. E., Drum, P. A., & Ehri, L. C. (1984). Does environmental print identification lead children into word reading? *Journal of Reading Behavior, 16*(4), 257–271. https://doi.org/10.1080/10862968409547520

McTigue, E. M., Solheim, O. J., Zimmer, W. K., & Uppstad, P. H. (2019). Critically reviewing GraphoGame across the world: Recommendations and cautions for research and implementation of computer-assisted instruction for word-reading acquisition. *Reading Research Quarterly, 55*(1), 45–73. https://doi.org/10.1002/rrq.256

Meganathan, R. (2011). Language policy in education and the role of English in India: From library language to language of empowerment. In H. Coleman (Ed.), *Dreams and realities: Developing countries and the English language* (pp. 57–85). British Council. https://www.teachingenglish.org.uk/sites/teacheng/files/Z413%20English%20Development%20Book.pdf

Melby-Lervåg, M., & Lervåg, A. (2011). Cross-linguistic transfer of oral language, decoding, phonological awareness and reading comprehension: A meta-analysis of the correlational evidence. *Journal of Research in Reading, 34*(1), 114–135. https://doi.org/10.1111/j.1467-9817.2010.01477.x

Melby-Lervåg, M., Lyster, S.-A. H., & Hulme, C. (2012). Phonological skills and their role in learning to read: A meta-analytic review. *Psychological Bulletin, 138*(2), 322–352. https://doi.org/10.1037/a0026744

Miglani, N., & Burch, P. (2019). Educational technology in India: The field and teacher's sensemaking. *Contemporary Education Dialogue*, *16*(1), 26–53. https://doi.org/10.1177/0973184918803184

Ministry of Education. (2021). *National initiative for proficiency in reading with understanding and numeracy.* https://www.education.gov.in/sites/upload_files/mhrd/files/nipun_bharat_eng1.pdf

Ministry of Human Resource Development. (2020). *National Education Policy.* https://www.education.gov.in/sites/upload_files/mhrd/files/NEP_Final_English_0.pdf

Mishra, R., & Stainthorp, R. (2007). The relationship between phonological awareness and word reading accuracy in Oriya and English: A study of Oriya-speaking fifth-graders. *Journal of Research in Reading, 30*(1), 23–37. https://doi.org/10.1111/j.1467-9817.2006.00326.x

Moats, L. C. (2000). *Whole language lives on: The illusion of" balanced" reading instruction*. DIANE Publishing. https://files.eric.ed.gov/fulltext/ED449465.pdf

Moats, L.C. (2009). Knowledge foundations for teaching reading and spelling. *Reading and Writing, 22*, 379–399. https://doi.org/10.1007/s11145-009-9162-1

Muralidharan, K., Das, J., Holla, A., & Mohpal, A. (2017). The fiscal cost of weak governance: Evidence from teacher absence in India. *Journal of Public Economics*, *145*, 116–135. https://doi.org/10.1016/j.jpubeco.2016.11.005

Muralidharan, K., Singh, A., & Ganimian, A. J. (2019). Disrupting education? Experimental evidence on technology-aided instruction in India. *American Economic Review*, 109(4), 1426–1460. https://doi.org/10.1257/aer.20171112

Nag-Arulmani, S. (2000). *Types and manifestations of learning difficulties in Indian classrooms* [Paper presentation]. First Orientation Programme for Schoolteachers, National Institute for Public Co-operation and Child Development (NIPCCD), Bangalore, India.

Nagarajan, R. (2021, July 3). 26% of schoolkids in English medium; nearly 60% in Delhi. *The Times of India.* https://timesofindia.indiatimes.com/india/26-of-schoolkids-in-english-medium-nearly-60-in-delhi/articleshow/84082483.cms

Nakamura, P. R., de Hoop, T., & Holla, C. (2019). Language and the learning crisis: Evidence of transfer threshold mechanisms in multilingual reading in South India. *The Journal of Development Studies, 55*(11), 2287–2305.

National Council of Education Research and Training. (2016). *Eighth all India school education survey.* https://ncert.nic.in/pdf/programmes/AISES/8th_AISES_Concise_Report.pdf

National Reading Panel. (2000). *Teaching children to read: An evidence-based assessment of the scientific research literature on reading and its implications for reading instruction (NIH Publication No. 00-4769).* National Institute of Child Health & Development.

https://www1.nichd.nih.gov/publications/pubs/nrp/Documents/report.pdf
Ngorosho, D. (2018). Enhancing the acquisition of basic reading skills in Kiswahili using GraphoGame. *Papers in Education and Development, 35.* http://journals.udsm.ac.tz/index.php/ped/article/view/1488
Nishanimut, S. P., Johnston, R. S., Joshi, R. M., Thomas, P. J., & Padakannaya, P. (2013). Effect of synthetic phonics instruction on literacy skills in an ESL setting. *Learning and Individual Differences*, 27, 47–53. https://doi.org/10.1016/j.lindif.2013.06.007
Odo, D.M. (2021). A meta-analysis of the effect of phonological awareness and/or phonics instruction on word and pseudo word reading of English as an L2. *SAGE Open, 11*(4). https://doi.org/10.1177/21582440211059168
Perkins, D. N., & Salomon, G. (1992). Transfer of learning. *International Encyclopedia of Education*, *2*, 6452–6457.
Piasta, S. B., & Hudson, A. K. (2022). Key knowledge to support phonological awareness and phonics instruction. *The Reading Teacher, 76*(2), 201–210. https://doi.org/10.1002/trtr.2093
Pittman, R. T., Zhang, S., Binks‐Cantrell, E., Hudson, A., & Joshi, R. M. (2020). Teachers' knowledge about language constructs related to literacy skills and student achievement in low socio‐economic status schools. *Dyslexia, 26*(2), 200–219. https://doi.org/10.1002/dys.1628
Puhakka, C. S., Lyytinen, H., & Richardson, U. (2015). Technology enhanced literacy learning in multilingual Sub-Saharan Africa : The case of GraphoGame Kikuyu and Kiswahili adaptations in Kenya. In P. A. M. Kommers, P. Isaias, & T. Issa (Eds.), *Perspectives on Social Media: A Yearbook* (pp. 183–190). Routledge.
Rao, C., Sumathi, T. A., Midha, R., Oberoi, G., Kar, B., Khan, M., Vaidya, K., Midya, V., Raman, N., Gajre, M., & Singh, N. C. (2021). Development and standardization of the DALI-DAB (dyslexia assessment for languages of India—Dyslexia assessment battery). *Annals of Dyslexia, 71*, 439–457. https://doi.org/10.1007/s11881-021-00227-z
Rayner, K., Foorman, B. R., Perfetti, C. A., Pesetsky, D., & Seidenberg, M. S. (2001). How psychological science informs the teaching of reading. *Psychological Science in the Public Interest*, *2*(2), 31–74. https://doi.org/10.1111/1529-1006.00004
Reddy, P. P., & Koda, K. (2013). Orthographic constraints on phonological awareness in biliteracy development. *Writing Systems Research, 5*(1), 110–130. https://doi.org/10.1080/17586801.2012.748639
Rice, M., Erbeli, F., Thompson, C. G., Sallese, M. R., & Fogarty, M. (2022). Phonemic Awareness: A Meta-Analysis for Planning Effective Instruction. *Reading Research Quarterly, 57*(4), 1259–1289. https://doi.org/10.1002/rrq.473

Richardson, U., & Lyytinen, H. (2014). The GraphoGame method: The theoretical and methodological background of the technology-enhanced learning environment for learning to read. *Human Technology*, *10*(1), 39–0. https://doi.org/10.17011/ht/urn.201405281859

Rodriguez-Segura, D. (2020). *Educational technology in developing countries: A systematic review.* University of Virginia EdPolicy Works Working Papers. https://curry. virginia.edu/sites/default/files/uploads/epw/72_Edtech_in_Developing_Countries. pdf.

Rose, J. (2006). *Independent review of the teaching of early reading final report.* U.K. Department for Education and Skills. http://dera.ioe.ac.uk/5551/2/report.pdf

Rowe, K. (2005). *Teaching reading: National inquiry into the teaching of literacy.* Department of Education, Science and Training, Australian Council for Educational Research. https://research.acer.edu.au/tll_misc/5/

Saine, N.L., Lerkkanen, M.K., Ahonen, T., Tolvanen, A., & Lyytinen, H. (2010). Predicting word-level reading fluency outcomes in three contrastive groups. Remedial and computer-assisted remedial reading intervention, and mainstream instruction. *Learning and Individual Differences, 20*(5), 402–414. https://doi.org/10.1016/j.lindif.2010.06.004

Saine, N.L., Lerkkanen, M.K., Ahonen, T., Tolvanen, A., & Lyytinen, H. (2011). Computer-assisted remedial reading intervention for school beginners at risk for reading disability. *Child Development, 82*(3), 1013–1028. https://doi.org/10.1111/j.1467-8624.2011.01580.x

Sampson, R., Johnson, D., Somanchi, A., Barton, H., Joshi, R., Seth, M., & Shotland, M. (2019). *The EdTech Lab Series: Insights from rapid evaluations of EdTech products*. Central Square Foundation. https://centralsquarefoundation.org/wp-content/uploads/EdTech%20Lab%20Report_November%202019.pdf

Segura, F., & Sommer, S. (2022, June 3). Edtech Should Be More Evidence Driven. *EdSurge*. https://www.edsurge.com/news/2022-06-03-edtech-should-be-more-evidence-driven?utm_campaign=site&utm_content=share-68

Seymour, P. H., Aro, M., Erskine, J. M., & Collaboration with COST Action A8 Network. (2003). Foundation literacy acquisition in European orthographies. *British Journal of Psychology, 94*(2), 143–174. https://doi.org /10.1348/000712603321661859

Sharma, K. (2021, January 26). How govt portal Diksha with '3 cr hits/day' has become a key tool for teachers during Covid. *The Print.* https://theprint.in/india/education/how-govt-portal-diksha-with-3-cr-hits-day-has-become-key-tool-for-teachers-during-covid/591678/

Shenoy, S., Wagner, R. K., & Rao, N. M. (2020). Factors that influence reading aquisition in L2 English for students in Bangalore, India. *Reading and Writing*, 33, 1809–1838. https://doi.org/10.1007/s11145-020-10047-z

Singh, N.C. (2015). *Dyslexia assessment for languages of India (DALI*). National Brain Research Centre.
Singley, M. K., & Anderson, J. R. (1989). *The transfer of cognitive skill* (No. 9). Harvard University Press.
Snow, P. (2017, May 12). Balanced literacy: An instructional bricolage that is neither fish nor fowl. *Pamela Snow.* http://pamelasnow.blogspot.com.au/2017/05/balanced-literacy-instructional.html
Torgesen, J. K., Wagner, R. K., & Rashotte, C. A. (1999). *Test of Word Reading Efficiency.* Pro-Ed.
Treiman, R., Mullennix, J., Bijeljac-Babic, R., & Richmond-Welty, E. D. (1995). The special role of rimes in the description, use, and acquisition of English orthography. *Journal of Experimental Psychology: General, 124*(2), 107–136. https://doi.org/10.1037/0096-3445.124.2.107
Trines, S. (2018, September 13). Education in India. *World Education News and Reviews.* https://wenr.wes.org/2018/09/education-in-india
UNESCO New Delhi. (2021). *State of the education report for India: No teacher, no class.* https://en.unesco.org/news/no-teacher-no-class-state-education-report-india-2021
Wadhwa, W. (2018). Equity in learning? In *Annual status of Education report (rural) 2018* (pp. 17–19). ASER Centre. http://img.asercentre.org/docs/ASER%202018/Release%20Material/aserreport2018.pdf
Washburn, E.K., Binks--Cantrell, E.S., Joshi, R.M., Martin--Chang, S., & Arrow, A. (2016). Preservice teacher knowledge of basic language constructs in Canada, England, New Zealand, and the USA. *Annals of Dyslexia, 66*(1), 7–26. https://doi.org/10.1007/s11881-015-0115-x
Wilson, A., Ahmed, H., Mead, N., Noble, H., Richardson, U., Wolpert, M. A., & Goswami, U. (2021). Neurocognitive predictors of response to intervention with GraphoGame rime. *Frontiers in Education*, *6*, 125. https://doi.org/10.3389/feduc.2021.639294
World Bank Group. (2019a). *India: Learning poverty brief.* https://thedocs.worldbank.org/en/doc/386361571223575213-0090022019/original/SASSACININDLPBRIEF.pdf
World Bank Group. (2019b, October 15). Learning poverty. *The World Bank.* https://www.worldbank.org/en/topic/education/brief/learning-poverty
World Literacy Foundation. (2018*). The economic and social cost of illiteracy.* https://worldliteracyfoundation.org/wp-content/uploads/2021/07/TheEconomicSocialCostofIlliteracy-2.pdf
Worth, J., Nelson, J., Harland, J., Bernardinelli, D., & Styles, B. (2018). *GraphoGame rime: Evaluation report and executive summary.* National Foundation for Educational Research. https://www.nfer.ac.uk/graphogame-rime-evaluation-report-and-executive-summary

Wouters, P., & Van Oostendorp, H. (2013). A meta-analytic review of the role of instructional support in game-based learning. *Computers & Education*, *60*(1), 412–425. https://doi.org/10.1016/j.compedu.2012.07.018

Ziegler, J., & Goswami, U. (2005). Reading acquisition, developmental dyslexia and skilled reading across languages: A psycholinguistic grain size theory. *Psychological Bulletin, 31*(1), 3–29. https://doi.org/10.1037/0033-2909.131.1.3

ORIGINAL PAPERS

I

GRAPHOLEARN INDIA: THE EFFECTIVENESS OF A COMPUTER-ASSISTED READING INTERVENTION IN SUPPORTING STRUGGLING READERS OF ENGLISH

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GraphoLearn India: The Effectiveness of a Computer-Assisted Reading Intervention in Supporting Struggling Readers of English

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India, a country with a population of more than 1.3 billion individuals, houses the world's second largest educational system. Despite this, 100 of millions of individuals in India are still illiterate. As English medium education sweeps the country, many are forced to learn in a language which is foreign to them. Those living in poverty further struggle to learn English as it tends to be a language which they have no prior exposure to and no support at home for. Low-quality schools and poor instructional methods further exacerbate the problem. Without access to quality education, these individuals continue to struggle and are ultimately never given the chance to break the cycle of poverty. The aim of this study was to determine whether GraphoLearn, a computer-assisted reading tool, could be used to support the English reading skills of struggling readers in India. Participants were 7-year-old, grade 3 students (N = 30), who were attending an English-medium public school in Ahmedabad, India. English was not a native language for any of the students and all were reading at a level below that of Grade 1 despite having attended school for 2 years. Half of the students played GraphoLearn (n = 16) while the other half played a control math game (n = 14) for 20–30 min a day, over a period of 8 weeks. GraphoLearn led to significant improvements in children's letter-sound knowledge, a critical factor in early reading development. Overall, the study opens doors for GraphoLearn as a potential intervention to support struggling readers of English in India, including those who are learning a non-native language and coming from at-risk backgrounds.

Keywords: GraphoLearn, reading intervention, computer-assisted learning, phonics, grapheme-phoneme correspondence, English language learners, India

INTRODUCTION

Despite international moves and agreements to improve literacy around the world, many developing countries are still struggling with high rates of illiteracy. India, a country with a population of 1.3 billion individuals, only has a literacy rate of 72% among those 15 years and older (UNESCO, 2015). In a country developing as quickly as India, an illiteracy rate which leaves 100 of millions as illiterates is highly concerning as it puts many individuals at risk of never being able to reach opportunities and act as contributing members of society. With 17 official languages (as recognized by the United Nations) and more than 700 dialects (Mitra et al., 2003; Dixon et al., 2011), and with 21% of the population, or 269 million people, living below the poverty line (The World Bank, 2011), solving India's literacy crisis is an extremely large task.

Education plays a major role in literacy and, therefore, some believe that one strategy to start combatting the problem may be to look at countries with successful education systems and borrow interventions that can be implemented elsewhere (Ojanen et al., 2015). Children in India, especially those living in poverty, face many problems in education. Slum and other low-income children are forced to attend low quality schools, which are under-resourced and use poor teaching methods (Cheney et al., 2005; Kingdon, 2007). With a country-wide push towards English medium education, these students are studying in a language which they may have no prior exposure to and no support at home for. Due to factors such as these, many children struggle to learn English and attain a quality education. In turn, many of these children will never have the option of higher education, and once again, they will find themselves stuck in the cycle of poverty. According to The World Bank (2012) 45% of the poor are illiterate as compared to 26% of the non-poor.

The purpose of this study was to determine whether GraphoLearn, a computer-assisted tool for reading instruction, originally created for struggling readers of Finnish, could be used to support struggling readers of English in India. The major focus is on slum children attending government-aided public schools in Ahmedabad, India, who are non-native speakers of English, and at high risk of never achieving fluent English literacy.

English in India

English as a language was originally brought to India by the British who arrived in the 1600s and established trade posts through the East India company (Mehrotra, 1998). English was used throughout the British rule between traders and merchants, as well as by Christian missionaries (Mehrotra, 1998). During this time, English was viewed as a language of the elite, a view that has been upheld even post Indian independence in 1947 (Mishra and Stainthorp, 2007). Being that India is a highly multicultural country, English has been maintained, and acts as a common bridging language across states (Mitra et al., 2003). British rule brought with it a tradition of English medium education to India (Annamalai, 2004) which was maintained as there was no other language throughout the country which would be accepted by the linguistic minorities (Mishra and Stainthorp, 2007).

In present day India, it is common for individuals to use a variety of languages in everyday life (Mishra and Stainthorp, 2007). It may even be that one language is used in the workplace or school, while another language is used in speaking to peers, and then the mother tongue is used in speaking to family and other relatives. Today, English is the only language that is taught in all states and in the most number of schools across the country (Annamalai, 2004). Individuals who speak English are coveted by employers (Mitra et al., 2003; Annamalai, 2004) and it has become a very important language, particularly in higher education (Mehrotra, 1998; Annamalai, 2004; Cheney et al., 2005), with the majority of high level institutions only providing instruction in English. As a result, English has the ability to influence the standard of living in India; with those having better English skills getting better job opportunities, and in turn better pay (Mehrotra, 1998; Mitra et al., 2003). As parents realize the opportunity that comes with learning English, many are actively choosing to enroll their children in English medium schools. This is true even for parents from slum areas who have started accepting that the ability to read, write, and speak in English will increase opportunity for their children (Mehrotra, 1998; Mitra et al., 2003; Dixon et al., 2011). Currently, there are 90 million children across various socioeconomic statuses that are becoming literate in English (Kaila and Reese, 2009).

However, children growing up in slum communities are at a large disadvantage when it comes to learning the English language (Annamalai, 2004). In English medium schools, English is the primary language of instruction, meaning that all subjects are taught in English, with regional and other languages taught as second and/or third languages. Slum children often have no exposure to English prior to entering school, as parents typically cannot speak or communicate in English. It is also likely that these parents are illiterate in their mother tongue as well (Dixon et al., 2011), meaning that their children will have no exposure to literacy in any language prior to school entry. According to Nag (2013) children who miss such supports, such as having a print rich environment with access to reading material or an adult to read to them, tend to develop profiles which are similar to those with dyslexia or other reading difficulties. Thus, children are at high risk even before they enter the school.

Parents from the lower levels of society, typically have two choices in terms of schools for their children; government -aided public schools or low-income, unaided private schools (Cheney et al., 2005). Due to the high demand for English, there has been a "mushrooming" of low-cost private schools (Tooley and Dixon, 2005), and now English is also taught as a primary language in public government schools. In most of these public and private schools, teaching quality is low and children are forced to rote learn a language they do not fully understand (Annamalai, 2004; Dixon et al., 2011). On the contrary, there are many private schools across the country which follow international board curriculum and provide high quality English education. However, these schools charge high fees making them inaccessible to the low-income population (Cheney et al., 2005).

According to the latest Annual Status of Education Report (ASER), 95.9% of children ages 6–14 are enrolled in school across India (2016). Although school enrollment is high, learning achievements of these enrolled children are consistently low (Kingdon, 2007). Across all languages, only 47.8% of children in Grade 5 are able to read a Grade 2 level text (ASER, 2016). When looking at English, of all surveyed children in Grade 3, only 19.3% could read simple words such as "day" or "sit" (ASER, 2016). Although the ASER report only surveys children in rural India, data from the National Achievement Survey (NAS) shows that the situation in urban India is not strikingly different. The NAS for Grade 3 students has three measures on the language assessment; listening comprehension, word recognition, and reading comprehension. Across the nation, the average score was

257 out of a total 500, leaving approximately 50% of Grade 3 students unable to perform at grade level (NCERT, 2014).

Grapheme-Phoneme Correspondences and Early Reading Acquisition

Learning to read in any language requires understanding the links between the spoken language and its written form. More specifically, those who are learning to read must understand the grapheme-phoneme correspondences (GPC's) that occur within a particular language. It has been well established that knowledge of grapheme-phoneme correspondences directly impacts fluent reading (e.g., Ehri, 2005) and such knowledge is necessary for further development of reading skills.

However, the ease of reading acquisition is greatly determined by the orthographic depth of a language. Many researchers agree that reading acquisition in English, is much more complicated than reading acquisition in many other languages, due to its deep orthography (see Seymour et al., 2003). The grapheme-phoneme correspondences in English are more complex and context-dependent and therefore, there is still some disagreement on how early reading instruction in English should proceed. Some argue that English, and other opaque orthographies, might be more effectively introduced through larger units, also known as rime units, rather than at the level of single graphemes and phonemes (Goswami, 1986, 1988), as they tend to be more consistent. It is believed that English-speaking children may benefit more if focus is put towards teaching these larger rime units and can then use rime analogies from words that they already know to read unfamiliar words as well (Goswami and Bryant, 1990).

However, when compared to instruction based on small units, some studies have failed to find any significant differences when comparing instruction based on grapheme-phoneme correspondence as compared to onset rime (e.g., Haskell et al., 1992; Levy and Lysynchuk, 1997). A study conducted by Christensen and Bowey (2005) compared children participating in two explicit, decoding programs, one which was based on orthographic rimes and a second which was based on grapheme-phoneme correspondences. The study also involved a control group which received implicit phonics instruction. Not surprisingly, it was found that both of the explicit instruction groups outperformed the implicit control group in reading and spelling. Interestingly, the study also showed differences between the orthographic rime group and the grapheme-phoneme correspondences group, with the grapheme-phoneme correspondences group performing better at reading and spelling unfamiliar words. The role of grapheme-phoneme correspondences in reading development have also been established amongst children who are non-native speakers of English. Researchers in Canada compared children who were either native speakers of English or native speakers of Punjabi, all of whom were attending school in English. They found that both groups of students were reliant on grapheme-phoneme correspondences when they were presented with unfamiliar words. Similarly, for both groups, errors in reading were due to the inability to apply grapheme-phoneme correspondences to unfamiliar words (Chiappe and Siegel, 1999) with poor readers being less skilled at this application.

Nevertheless, there tends to be consensus that early reading instruction through phonics (individual phonemes or onset-rime) should follow a systematic approach in which children are taught to connect spoken language segments to their corresponding written forms (Wyse and Goswami, 2008; Kyle et al., 2013). Automatization of this phonetic knowledge of a language plays a critical role in early reading development and later reading skill (Ehri, 1998; Juel and Minden-Cupp, 2000).

Reading Instruction: From Rote Memorization to Systematic Phonics

Children studying English in India, particularly those in low-income schools, are taught English in a rote manner (Annamalai, 2004; Dixon et al., 2011). Students learn the names of letters, rather than sounds, and are then expected to learn "common" words as a whole in which students essentially learn to recognize words through sight. Like words, sentences are also learned through a method of rote memorization in which someone points to the words written on the board, which are then chanted by the rest of the class (Dixon et al., 2011). Through such rote learning methods, children are unable to blend or decode unfamiliar words and are therefore, only able to "read" words which are familiar to them, but that too often with limited comprehension. The NAS uses reading comprehension as the primary measure of language knowledge of Grade 5 students across India. In 2015, it was found that nationally Grade 5 students only scored an average of 48.2% (out of a total of 100%) on the reading comprehension assessment (NCERT, 2015). Thus providing evidence against such rote methods of reading instruction to teach English in India.

One of the most popular methods of early reading instruction in English-speaking countries has been through systematic phonics. The phonics approach involves explicitly instructing readers on the linkages that exist between letters and their corresponding sounds, and how that is then used to read words. Synthetic phonics approaches, in which children learn small units of language (graphemes and phonemes) are believed to be the most logical way to support early reading development (e.g., Seymour and Duncan, 1997; Hulme et al., 2002). Major correspondences are taught, as well as vowel sounds, digraphs, blends, onsets, and rimes (Ehri et al., 2001). There is ample support for systematic, synthetic phonics programs among native speakers of English (e.g., Ehri et al., 2001; Johnston and Watson, 2005). Fortunately, there is also strong evidence in favor of synthetic phonics programs for children learning English as a second language. A study by Stuart (1999) looked at reading instruction for 5-year-old children through a synthetic phonics program, Jolly Phonics, versus a more holistic program which placed no explicit importance on phonics. Majority of the sample (N = 96 out of 112) were children who were learning English as a second language. Results showed a significant positive effect of the Jolly Phonics intervention on the children's reading and writing development which persisted even a year after the initial intervention. Based on these results, researchers concluded that early structured, rapid, and focused teaching of phonetic manipulation actively supports development of this knowledge, even for children who are non-native speakers of the language (Stuart, 1999). A follow up study by Stuart also showed that even if children have not been taught using phonics at the start of school, they can catch up through structured and intensive phonics training (Stuart, 2004).

Such findings of the effectiveness of phonics teaching among second language learners is important for the Indian context as children in India are predominantly bilingual (and in some cases even multilingual), which creates a unique educational situation. Most children are exposed to their mother tongue prior to entering school, upon which they may begin to study in a language which they have no previous exposure. If the mother and father happen to speak different languages, then they may already encounter two different languages before starting formal schooling (Mishra and Stainthorp, 2007).

Synthetic phonics approaches have made their way to developing countries more recently; India being one such country of study. Dixon and colleagues tested the Jolly Phonics intervention with children attending English-medium, low-income private schools in Hyderabad, India. There was an experimental group which received the intervention for an hour per day for 6 months by the teacher, and a control group which received the traditional English instruction, typically involving rote-learning and whole word recognition. Results showed a statistically significant difference between the experimental and control groups, with the experimental group performing better on tasks of reading, spelling, and sounding out letters and words (Dixon et al., 2011). Effect sizes (*d*) were particularly strong for tasks assessing sound value of letters (16.18), blending (1.20), sentence dictation (1.01), and spelling (.86). Findings such as these strongly support the idea that phonics interventions could be successful to improve emergent English literacy in India.

Why Technology?

As it can be seen, there are a number of factors working against slum community children in India, when it comes to learning to read in English. Coming from homes, where parents may also be illiterate, children are suddenly forced to learn in a language which they may have no prior exposure to. Mother tongue instruction also may not be seen as an ideal option in a place like India, where English is given such high importance and has the potential to open many more doors. However, the rote methods teachers are currently using are clearly not helping students to achieve. Thus, the children are put in a situation where, although they are attending English medium schools, they may never acquire sufficient English literacy. The few studies which have been done using synthetic phonics instruction to teach English in India have produced promising results (Dixon et al., 2011). However, due to the numerous demands faced by teachers in India, as well as a potential lack of skill, changing instructional methods may seem intimidating for many. Technology, on the other hand, has the potential to help teachers overcome some of these barriers, and in turn allow them to provide the high-quality literacy instruction that all children deserve.

India has always been a strong player in the IT industry (Mitra et al., 2003; Kingdon, 2007). The Indian Market Research Bureau along with the Manufacturers' Association for Information Technology (MAIT-IMRB) has reported the tablet market in India to be growing at a rate of 73% (as cited in Central Square Foundation, 2015). Smartphone use is also becoming widespread as more and more low cost models come on the line (Central Square Foundation, 2015). As a result, the Indian government has also been actively working to integrate technology into the educational space through various initiatives. One such initiative is the "ICT@Schools" scheme. According to the Ministry of Human Resource Development, the government has spent 2585 crore Indian rupees (approximately 38 million USD), to install technological infrastructure in about 86,000 schools across the country (as cited in Central Square Foundation, 2015).

Researchers have found that not only is technology-led instruction benefiting children's learning (Banerjee et al., 2007), it is also cost effective and time effective (Muralidharan et al., 2017). Insights from studies across the educational technology sector in India have shown the benefits of, and continuing need for, technology that allows for differentiated instruction through personalized learning (Central Square Foundation, 2015). Though technology is greatly influencing modern educational spaces, there has been criticism against solely using technology as an intervention. A meta-analysis comparing technology use for direct versus support instruction resulted in a slightly greater effect for support instruction (see Tamim et al., 2011). Supporting results have been found when technology as a teacher compliment versus a teacher substitute was studied in the context of India. Linden (2008) found that students who received a math intervention as a substitute to teacher delivered curriculum performing significantly worse than students who received the intervention as a compliment to teacher instruction. Similarly, a study comparing the effects of a computer-based intervention to teacher implemented activities found that different students benefited from different interventions, with the lower performing students benefiting more from the teacher implemented activities and the higher performing students benefiting more from the computer-based intervention (He et al., 2008).

The GraphoLearn Method

GraphoLearn,[1] previously known as GraphoGame, is a theoretically driven computer-assisted tool for early reading that provides training on the connections between spoken and written language by explicitly instructing on grapheme-phoneme correspondences. The structure of the game is based on a theory of teaching small units, or 1–2 phonemes first, as this phonetic knowledge has been shown to be a strong predictor of later reading skill (e.g., Seymour and Duncan, 1997; Hulme et al., 2002). It was originally devised for readers of a transparent orthography, Finnish, based on longitudinal data that was collected through the Jyväskylä Longitudinal Study of Dyslexia (Lyytinen et al., 2007, 2009; Richardson and Lyytinen, 2014).

[1] http://info.grapholearn.com/

The Finnish version of GraphoLearn has been adapted to other languages around the world, English being one, and results have been promising in many countries across various languages (e.g., Saine et al., 2011; Kyle et al., 2013; Ojanen et al., 2015; Ruiz et al., 2017). To date, there has been no study which has used GraphoLearn to support non-native speakers of English.

There are two GraphoLearn English versions GraphoLearn English-Rime and GraphoLearn English-Phoneme. Prior to the current study, there has only been one published study done investigating GraphoLearn English. Kyle et al. (2013) tested the efficacy of the two versions of GraphoLearn English as a supplementary tool for students who were native English speakers in the United Kingdom. Results showed significant improvements in basic reading skills of the intervention group as compared to the controls for both game versions, but were unable to conclude that one version was more effective than the other. In the present study, GraphoLearn English-Rime was utilized. It incorporates the idea of teaching slightly larger rime units in addition to single grapheme-phoneme correspondences due to the orthographic complexity of English as a language (e.g., Goswami, 1986, 1988). In both game versions players are first introduced to single grapheme-phoneme correspondences. However, rather than introducing them all at once, in GraphoLearn English-Rime, grapheme-phoneme correspondences are introduced in sets of about 7–8 items. These individual letters are then combined to form rime units, and finally whole words. Later in the game, players are also shown whole words in which they must isolate or blend various grapheme-phoneme correspondences or rime units. Presentation of the grapheme-phoneme correspondences proceeds from the most frequent and consistent to the more infrequent and least consistent (Kyle et al., 2013). Kyle et al. (2013) reported that for the game version used in this study, effect size was large for BAS spelling (0.66) and TOWRE non-word reading (1.43) and medium for BAS reading (0.66) and TOWRE sight word reading (0.53) (Kyle et al., 2013).

The Present Study

The study reported here examined the efficacy of GraphoLearn, a computer-assisted reading tool, in improving basic reading skills of English by supporting the development of grapheme-phoneme knowledge, reading, and spelling ability of slum children in India. GraphoLearn was provided as a supplement to teacher instruction to third grade students in an English medium, government-aided public school in Ahmedabad, India. The school was approached based on information retrieved from the class teacher which showed the children as having very low literacy levels. We chose Grade 3 in order to assume that the children had at least 2 prior years of spoken English exposure (starting from Grade 1). Based on previous studies using synthetic phonics (Stuart, 1999; Stuart, 2004; Dixon et al., 2011) and based on previous GraphoLearn studies (Kyle et al., 2013), we expected to see improvements in student performance.

MATERIALS AND METHODS

Ethics Statement

Permission to run the study was taken from the Ahmedabad Municipal Corporation School Board, along with the principal and the class teacher. Parents of the children (both pilot and full study) provided written informed consent prior to the start of the intervention. The study was carried out in accordance with guidelines as given by the University of Jyväskylä Ethics Committee. An ethics approval was not required as per the University of Jyväskylä Ethics Committee guidelines and national regulations. However, a statement from the Ethics Committee can be provided upon request.

Pilot

Prior to the start of the full study, a pilot was conducted including 16 children from a second government-aided public school. These students were also in Grade 3 and had similar demographics as the children who participated in the full study. The pilot phase was run for 3 weeks and the primary purpose of the pilot phase was to experience the type of difficulties which may arise in the full study in a hope to circumvent such difficulties later. After the pilot period, there were some changes that were made prior to the start of the full study. The math game was changed for the controls as the original game which was selected was not long enough for students to play throughout the entire study period. Another change was to the paper-pencil tasks. It was originally planned to conduct a standardized phoneme deletion task as used by Kyle and colleagues (Kyle et al., 2013). However, when attempted with the children during the pilot, it was obvious that most children did not understand the task. Therefore, the standardized phoneme-deletion task was not included in the full study.

Participants

Thirty-one third graders, ages 7–8 participated in the study. Data provided by the teacher showed that the children, on average, were performing drastically below grade level in literacy. Due to the lack of specialists in the school, it was unknown if any children had additional special needs in learning, but no students had any formal diagnoses of such problems. All of the participating students were consented, at the end of second grade before they left for summer holidays to ensure that the study could begin as soon as possible once they returned. Parents were invited to the school and taken through the consent form as many were illiterate in English. In total, 43 parents provided written informed consent, however, only 31 children ended up participating in the study as some children dropped out of the school prior to the start of the study while other children had extremely irregular attendance or joined the school after the start of the study and therefore could not be included.

Students were randomly allocated to either the experimental group which played GraphoLearn (n = 16) or the control group which played a math game (n = 15). Groups were primarily matched based on age and gender, but basic reading skills, such as letter-sound knowledge, were also considered based on the information provided by the teacher. All students came from low-income homes, with a majority living below poverty line, and all students were learning English as a second or third language, with no exposure at home to English. All the children, except for one, had been enrolled in the school from Grade 1 and they had all been in the same classroom with the same teacher in both Grades 1 and 2. At the end of the study, there were three students who were unable to participate in all or some parts of the post-test due to illness. One student's data from the control group has been removed because they did not participate in any of the post testing. The other two students' data, both of whom were in the GraphoLearn group, was not removed because one participated in the GraphoLearn post-tests and the other participated in the paper-pencil post-tests. Significance values and effect sizes were not affected by eliminating these students' data, and therefore their data has been retained. Final group sizes at post-test were $n = 16$ for the GraphoLearn group and $n = 14$ for the control group. As a reward for the participation and cooperation of the class teacher and students involved, a set of 20 English story books were donated to the classroom at the end of the intervention period.

Procedure

Both groups of children played their respective games (GraphoLearn versus math) for 20–30 min per day, 6 days a week, over a period of 8 weeks. The children played the game on an individual tablet with headphones. All play was done during the regular school day where children were pulled out of their classroom in batches of 12 and then taken to a separate room where the tablets were set up for them. The researcher was present during all play sessions with the students.

GraphoLearn

GraphoLearn provides adaptive practice in which players see a set of letters or letter strings and hear a corresponding speech sound. Players are expected to select the correct written unit from the 4 to 7 options that correspond to the sound they hear from the headphones. GraphoLearn requires players to create an individual avatar after which they are taken through a series of streams which are divided into levels GraphoLearn English-Rime has a total of 25 streams. Each stream contains anywhere from 5 to 9 levels. The first seven streams start with a level with introduces players to a small set of individual grapheme-phoneme correspondences (7–8 items), some of which are new and others which are review from previous streams. Once these are introduced, they are then combined to form larger rime units. These larger units are then presented in the context of words. Further in the game, players are introduced to more complex grapheme-phoneme correspondences (e.g., blends and digraphs) and sounds which have multiple possible spellings. After every four streams, there is an assessment stream in which players are assessed on letter-sounds, rime units, and word recognition. Throughout the game, players are presented with auditory targets which they then must match with the correct visual target out of items presented on the screen. The streams are ordered according to difficulty, starting from the easiest and progressing to the more difficult connections present between spoken and written English. To support spelling skills, word formation levels are present in 15 streams. Players are presented with blocks on the screen containing either individual letters or onset and rime patterns which they then have to drag into boxes in the correct order to spell a target word (see **Figure 1**). In order to further support the development of phonological awareness, there are rhyming tasks present in 11 of the streams requiring players to select the target that rhymes with the auditory target they are presented with. In all the levels, if players choose incorrectly, they

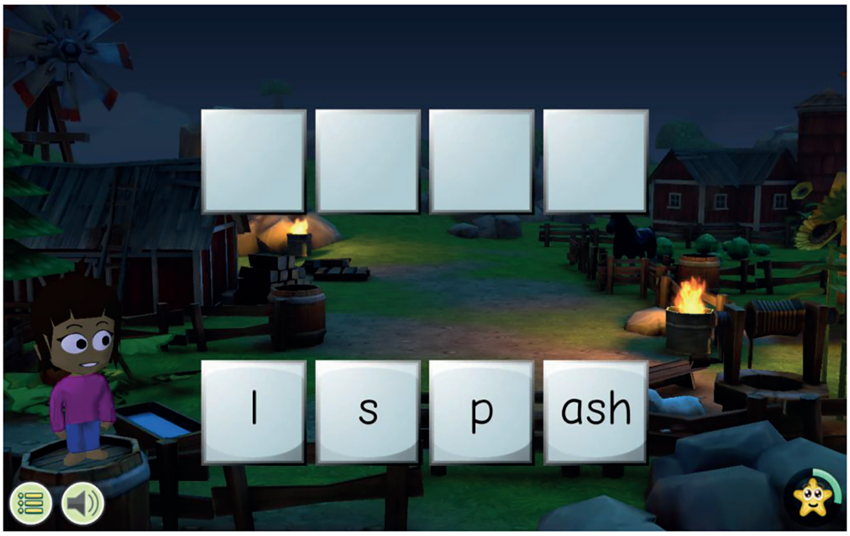

FIGURE 1 | An example of the screen during a word formation task in stream six.

are provided with automatic feedback, allowing them to correct themselves. Players must score above 80% on each level within a stream in order to move on to the next stream. To further build motivation, players are rewarded within each level with stars and coins which they can trade in to purchase things for their avatar. Data from the game is automatically saved to an external server when players exit the game so long as the device has an active internet connection (For a detailed description of GraphoLearn English see Kyle et al., 2013).

Math Game

The math game played by the control group was a Grade 3 level game called "Math for Kids" selected from the Google Play store. It provided students with basic operations problems (addition, subtraction, and multiplication) and students were required to select the correct answer out of four targets provided. Students could select out of three degrees of difficulty (easy, medium, and hard) and their progress in the game was saved meaning they could continue every session where they last left off. The math game was similar to GraphoLearn in that within each level there were multiple sublevels. The game rewarded children with stars and children were instructed to move on to the next level only after collecting at least two stars. The game provided no visual or auditory English input other than at the beginning when children had to select their level. The main purpose of the math game was to ensure that both groups of children spent equivalent amounts of time in the classroom versus outside of the classroom using the technology. As it can be seen in **Table 1**, there were no significant differences in the number of days played or playing times between the two groups.

Measures and Assessment Procedure

Students were assessed at pre and post intervention using three tasks in the GraphoLearn software and four paper-pencil tasks. The in-game assessment included the following tasks: letter-sound knowledge, rime unit recognition, and whole word recognition. The standardized paper-pencil tasks included the following tasks: the Single Word Reading subtest from the British Ability Scale (BAS II; Elliot et al., 1996), and the Test of Word Reading Efficiency (TOWRE; Torgesen et al., 1999) which included sight word reading and non-word reading. Students also completed a modified version of the spelling subtest from the BAS II. Students were pre-tested and post-tested by the researcher in the days preceding and the days following the intervention period. Students were pulled out of the class and completed the BAS II reading, TOWRE sight words, and TOWRE non-words tasks one-on-one with the researcher. The BAS II spelling assessment was given as a whole class dictation and the GraphoLearn in-game assessments were given to students in groups of 12 on the tablets. Both the GraphoLearn and control groups were given basic instructions on how the GraphoLearn assessments work prior to the start of the assessment tasks, and all students were instructed to inform the researcher once they finished an assessment task, and prior to starting the next assessment task. Through this, it was ensured that children were not playing levels which they should not be and all three assessment tasks were only being played once at pre-test and once at post-test.

TABLE 1 | Group characteristics.

Characteristic	GraphoLearn	Control	
n (Pre-Test)	16	14	–
n (Post-Test)	15	14	–
Gender			
Male	8	7	–
Female	8	7	–
Age (months)	91.94 (0.63)	91.00 (0.84)	$t(28) = 0.91$
Playing time (min)	470.7 (40.8)	457.3 (68.0)	$t(20.7) = 0.64$
Playing days	21.3 (1.7)	20.8 (3.1)	$t(19.5) = 0.50$

In-Game Assessments

All students completed three in-game assessments in GraphoLearn. The letter-sound task required children to pick the correct letter, out of the options, that corresponded with the sound which was presented to them (see **Figure 2A**). The rime unit task required children to pick the correct 2–3 letter string that corresponded to the pronunciation presented to them (see **Figure 2B**). Finally, the word-recognition test required children to pick the correct word to that which was presented to them (see **Figure 2C**). In all three tasks, players were presented with an auditory target which they were required to match with a visual target, just as in the rest of the game. In total, the letter sounds task contained 24 trials, the rime units task contained 24 trials, and the word recognition task contained 47 trials. The game would discontinue for the rime units task and the word recognition task if players chose incorrectly more than 50% of the time. The average number of trials played within all three tasks are given in **Table 2**. Both the experimental and control groups completed the assessment level prior to and at the end of the intervention period.

Paper-Pencil Assessments: Reading

All students in the study completed the Single Word Reading subtest from the British Ability Scale II (BAS II; Elliot et al., 1996) which measures single-word reading accuracy. The test was administered according to the manual and required children to read single-words of increasing difficulty which are listed in groups of 10. The test is discontinued after children miss eight or more words within one group. Internal reliability of the BAS II word reading task has been reported to be 0.98 and test-retest reliability has been reported to be 0.97 as per test review (Thomson, 1997). Students also completed the Test of Word Reading Efficiency (TOWRE; Torgesen et al., 1999). The TOWRE requires students to accurately read aloud a list of sight words and non-words for 45 s. Practice words were given for each section. Internal reliability ranges from 0.86 to 0.98, and test-retest reliability has been reported to be between 0.82 and 0.97 for both tasks, as per test review (Tanna, 2009). It is important to note that these assessments are not standardized for Indian children and therefore only raw scores are provided.

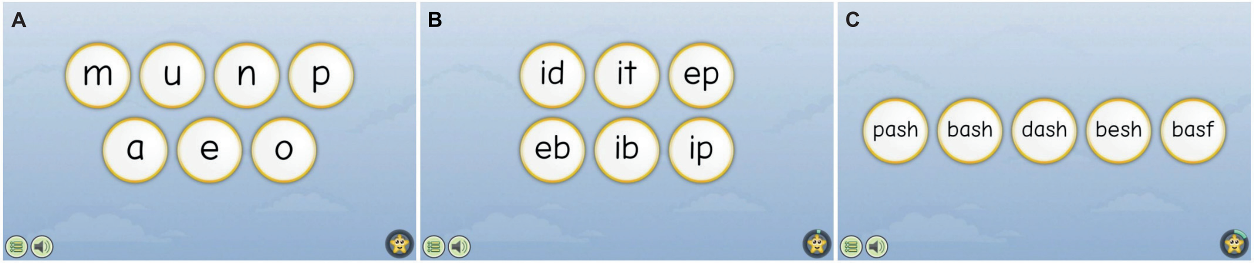

FIGURE 2 | Example screens from the GraphoLearn in-game assessments **(A)** is from the letter sounds task, **(B)** is from the rime units task, and **(C)** is from the word formation task.

TABLE 2 | Average number of trials completed within the in-game assessments at pre and post-test.

	Pre-test	Post-test
Letter-sounds	24	24
Rime units	4.97	8.10
Word recognition	6.87	8.71

Paper-Pencil Assessments: Spelling

All students also completed a spelling subtest which was taken from the British Ability Scale II (Elliot et al., 1996). The task contained a mixture of verbs, nouns, and adjectives, some of which can be spelled phonetically. The dictation test was not carried out according to the instructions suggesting different starting points based on age. Rather, the first 30 words out of the list were dictated to all students with the accompanying sentence. The word and an accompanying sentence were said a maximum of three times and students were expected to write down the word. The score was the number of correctly spelled items out of 30.

Fidelity to the Program

Fidelity to the GraphoLearn intervention was controlled by the detailed game logs sent to the GraphoLearn server. These logs include the number of days played and seconds spent playing. The first and last play day were also recorded. For the control group, days and time (in minutes) were recorded manually by the researcher. In addition, the primary researcher was present through all play sessions to ensure that the children were engaged in playing the respective games.

RESULTS

Prior to analyses, the distributions of all measures were assessed for normality. The BAS II reading measure at pre-test had two scores which were outliers and caused a right-skewed distribution. The TOWRE non-words measure at pre-test had one score which was an outlier and caused a right-skewed distribution. These scores were winzorized (replaced with a value that was closer to the distribution while retaining the order of values) to meet the assumption of normality. The remaining measures (GraphoLearn letter-sounds, GraphoLearn rime units, and GraphoLearn word recognition, TOWRE sight words, spelling) all produced a normal distribution at both time points.

Pre-test and Post-test Group Comparisons

The pre-test and post-test means and standard deviations in the two study groups, as well as group comparison results, are reported in **Table 3** for the GraphoLearn tasks and **Table 4** for the paper-pencil tasks.

First, an independent samples t-test was conducted to examine if there were group differences at pre-test or post-test. Due to the small sample size, group differences were also analyzed using non-parametric measures (Mann–Whitney U) but as the results did not differ from those given by the t-test, and therefore, the t-test results are reported. Effect sizes and their confidence intervals at pre-test were also calculated for all measures using Cohen's d with pooled standard deviation. The criteria as that defined by Cohen (1988) is being used

TABLE 3 | Descriptive statistics and group comparisons on GraphoLearn tasks.

Measure	Assessment	GraphoLearn *M (SD)*	Control *M (SD)*	*t*	Group effect	Time effect	Interaction effect
Letter-sounds	Pre-Test	33.3% (11.2)	36.3% (8.7)	$t(28) = -0.81$	$F(1,27) = 12.95^{***}$	$F(1,27) = 25.91^{***}$	$F(1,27) = 44.87^{***}$
	Post-Test	63.9% (18.0)	32.1% (10.6)	$t(27) = 5.73^{***}$			
Rime units	Pre-Test	16.6% (16.7)	13.6% (15.6)	$t(28) = 0.50$	$F(1,27) = 3.09$	$F(1,27) = 18.24^{***}$	$F(1,27) = 3.13$
	Post-Test	39.4% (20.5)	23.2% (17.0)	$t(27) = 2.31^{*}$			
Word recognition	Pre-Test	30.7% (16.3)	29.2% (19.8)	$t(28) = 0.23$	$F(1,27) = 1.03$	$F(1,27) = 25.13^{***}$	$F(1,27) = 2.68$
	Post-Test	49.0% (12.1)	39.1% (13.5)	$t(27) = 2.07^{*}$			

$^{*}p \le 0.05$, $^{**}p \le 0.01$, $^{***}p \le 0.001$.

TABLE 4 | Descriptive statistics and group comparisons on paper-pencil tasks.

Measure	Assessment	GraphoLearn *M* (*SD*)	Control *M* (*SD*)	*t*	Group effect	Time effect	Interaction effect
BAS II reading	Pre-Test	15.9(11.5)	14.4(12.0)	$t(28) = 0.72$	$F(1,27) = 0.02$	$F(1,27) = 12.39^{**}$	$F(1,27) = 0.72$
	Post-Test	19.7(13.7)	20.1(18.6)	$t(27) = -0.07$			
TOWRE sight words	Pre-Test	15.6(9.2)	18.3(13.7)	$t(28) = -0.63$	$F(1,27) = 0.15$	$F(1,27) = 10.98^{**}$	$F(1,27) = 0.67$
	Post-Test	19.5(12.8)	20.5(13.2)	$t(27) = -0.22$			
TOWRE non-words	Pre-Test	6.5(4.2)	7.6(4.9)	$t(28) = 0.53$	$F(1,27) = 0.02$	$F(1,27) = 7.86^{**}$	$F(1,27) = 1.23$
	Post-Test	9.3(6.3)	8.8(6.4)	$t(27) = 0.23$			
Spelling	Pre-Test	10.1(8.5)	12.2(8.9)	$t(28) = -0.66$	$F(1,27) = 0.09$	$F(1,27) = 11.95^{**}$	$F(1,27) = 3.67$
	Post-Test	13.7(8.1)	13.3(8.6)	$t(27) = 0.12$			

$^*p \le 0.05$, $^{**}p \le 0.01$, $^{***}p \le 0.001$.

in which $d \ge 0.2$ is a small effect, $d \ge 0.5$ is a medium effect, and $d \ge 0.8$ is a large effect. The results (see **Table 3**) showed that there were no pre-test group differences in the GraphoLearn tasks. Although effect size was small for letter-sounds (0.30) in favor of the control group, the confidence interval crossed zero. At post-test, group differences in favor of the GraphoLearn group were significant for all GraphoLearn tasks; letter-sounds ($t(27) = 5.73$, $p = 0.000$), rime units ($t(27) = 2.31$, $p = 0.029$), and word recognition ($t(27) = 2.07$, $p = 0.048$). Effect sizes were large for GraphoLearn letter-sounds (2.13) and GraphoLearn rime units (0.85), and medium for GraphoLearn word recognition (0.77), however, only the GraphoLearn letter-sounds had a confidence interval that did not cross zero (1.22, 3.04).

On the paper-pencil tasks, results revealed no significant differences between the groups at neither pre-test nor post-test (see **Table 4**). Effect sizes (d) for the group differences at pre-test were very small and supported the t-test finding of no significant group differences in BAS II reading (0.13), TOWRE sight words (0.24), TOWRE non-words (0.23), and spelling (0.24). Effect sizes for the paper-pencil tasks at post-test were also very small and again supported the t-test finding of no significant group differences in BAS II reading (0.03), TOWRE sight words (0.08), TOWRE non-words (0.09), and spelling (0.05). Confidence intervals for all paper-pencil measures crossed zero at both pre-test and post-test.

Group Comparisons of Development From Pre-test to Post-test

Repeated measures ANOVA was used to compare the effects of time (change from pre-test to post-test), group (GraphoLearn versus control), and time*group interaction on the scores (group differences in change).

For the GraphoLearn tasks (letter-sounds, rime units, and word recognition), there was a significant main effect of time on all three tasks (See **Table 3**), with both groups showing improvement from pre- to post-test (see **Figure 3**). For the letter-sounds task, there was a significant main effect for group, as well as a significant interaction effect for time*group, with the GraphoLearn group showing significantly higher scores and faster development than the control group. For the rime unit task, there were no significant main effects for group or interaction effects for group*time. However, the p-values for both the main effect and interaction effect were close to the 0.05 significance level ($p = 0.09$). Finally, for the word recognition task there were no significant group effects or interaction effects for group*time. For the paper-pencil tasks (BAS II reading, TOWRE sight words, TOWRE non-words, and spelling), there was a main effect for time on all measures (see **Table 4**), with both groups showing improvements from pre to post-test (see **Figure 4**). There were, however, no significant effects of group, nor were there significant time*group interactions for the paper-pencil assessments.

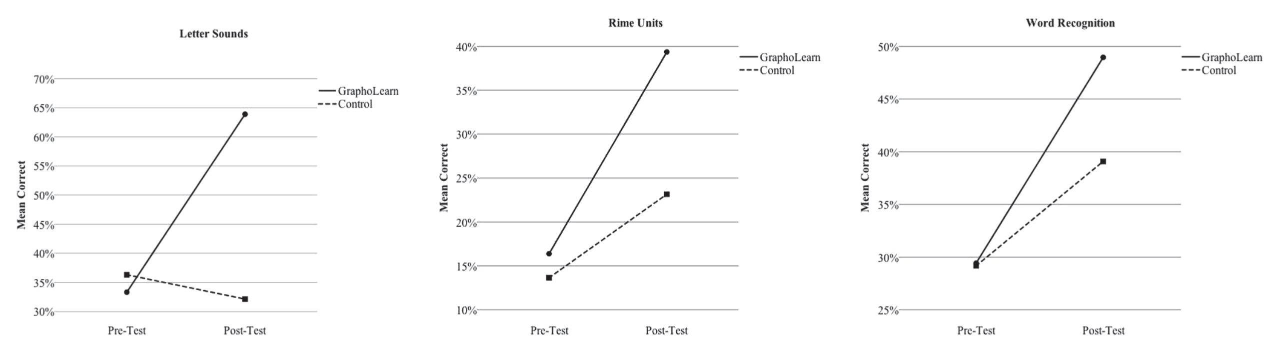

FIGURE 3 | Group Comparisons of Development from Pre-test to Post-test on GraphoLearn Tasks.

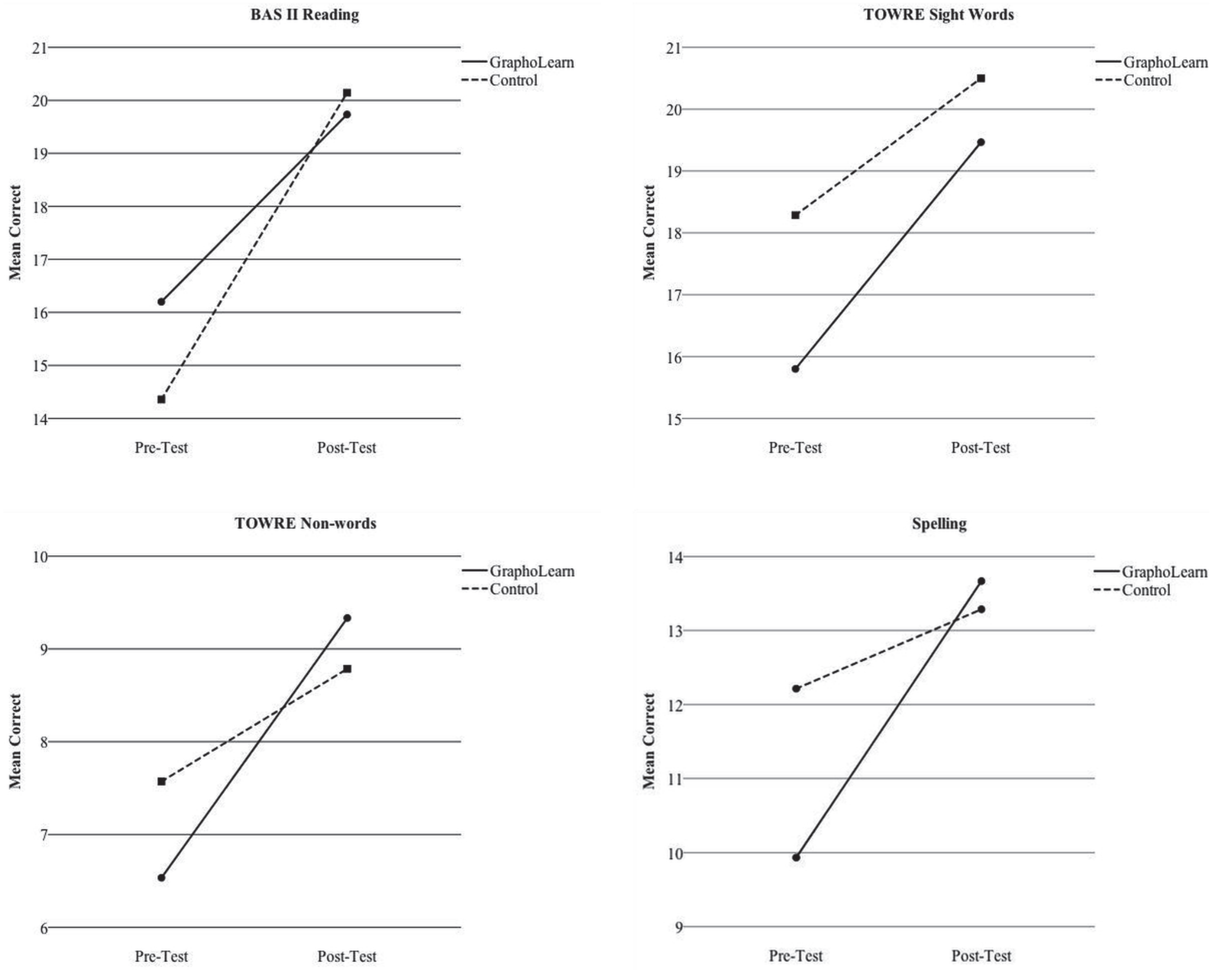

FIGURE 4 | Group Comparisons of Development from Pre-Test to Post-Test on Paper-Pencil Tasks.

Group Comparisons of Gain Scores

Finally, groups were compared using gains scores. Gain scores were calculated by subtracting the pre-test score from the post-test score for each individual. Means and standard deviations of the gain scores for both groups are given in **Table 5**, along with group comparisons, effect size (Cohen's *d*), and confidence intervals for the effect sizes for GraphoLearn versus control. The standard errors of the effect sizes are given in parentheses.

In regards to the GraphoLearn tasks, there was a very large effect on the letter-sound task (2.49) and the confidence interval did not cross zero (1.52, 3.47), allowing us to conclude of a significant difference in favor of the GraphoLearn group. There were medium effects for the rime units (0.64) and word recognition (0.52) tasks, however, confidence intervals on these measures crossed zero. In regards to the paper-pencil tasks, GraphoLearn group versus control group comparison had medium effect sizes on TOWRE non-word reading (0.62) and spelling (0.74). Effect size was small for TOWRE sight word reading (0.31) and almost zero for BAS II single-word reading. Confidence intervals for all paper-pencil measures crossed zero (see **Table 5**).

DISCUSSION

The present study examined whether GraphoLearn, a computer-assisted reading tool, could effectively support the development of basic English reading skills of struggling readers in India. The participants were Grade 3 slum children in India, who were learning English as a non-native language and who typically had no exposure to English outside of the school environment. Students were divided into either the control or experimental group with the control group playing a simple math game and the experimental group playing GraphoLearn for 20–30 min per day, over a period of 8 weeks. Despite a short play period (∼7.5 h) and limited sample size, participants made

TABLE 5 | Means and effect sizes of group differences in gains.

Measure	GraphoLearn *M* (*SD*)	Control *M* (*SD*)	*t*	Effect Size *d* (*SE*)	Confidence interval (95%)	
					Lower	Upper
n	15	14				
GL letter-sounds	30.57% (15.78)	−4.17% (11.67)	$t(27) = 6.70^{***}$	2.49 (0.35)	1.52	3.46
GL rime units	22.98% (19.82)	9.51% (21.16)	$t(27) = 1.77$	0.66 (0.24)	−0.09	1.41
GL word recognition	19.53% (13.01)	9.91% (18.35)	$t(27) = 1.64$	0.61 (0.18)	−0.17	1.35
BAS II reading	3.53 (7.03)	3.43 (4.09)	$t(27) = 0.05$	0.02 (0.44)	−0.71	0.75
TOWRE sight words	3.67 (1.25)	2.21 (4.71)	$t(27) = 0.82$	0.30 (0.27)	−0.43	1.04
TOWRE non-words	2.80 (4.04)	0.64 (3.46)	$t(27) = 1.54$	0.57 (0.30)	−0.17	1.32
Spelling	3.73 (3.86)	1.07 (3.61)	$t(27) = 1.92$	0.71 (0.28)	−0.04	1.46

$^{***}p \leq 0.001$.

significant gains and effect size was promising for at least the letter-sound knowledge, a critical skill for early reading development.

The GraphoLearn intervention group showed the greatest improvements on the letter-sounds task. Group differences were significant, effect size of the gains from pre to post-test was large, and the confidence interval of the effect size did not cross zero, thus allowing us to conclude that there was in fact an effect of the intervention on the difference between the two groups for the letter-sounds knowledge task.

The results show that GraphoLearn can effectively support the development of English letter-sound knowledge in Indian children, despite the fact that participants were non-native speakers and were exposed to the intervention for a limited amount of time. The ability for GraphoLearn to support the development of letter-sound knowledge to this extent is of importance as letter-sound knowledge has been identified as a critical building block in early reading development, even for non-native readers of English (Muter and Diethelm, 2001). There is also evidence in favor of letter-sound knowledge affecting early literacy skills, particularly word reading (Hulme et al., 2012). GraphoLearn can be seen as a beneficial intervention even for bilingual children supporting the previous finding suggesting that bilingual children can benefit just as much as native English speakers when they are provided with literacy interventions that involve explicit emphasis on grapheme-phoneme relationships (Lesaux and Siegel, 2003).

Although the rime unit and word recognition tasks had effect sizes that were medium to large, confidence intervals crossed zero. Due to our small sample size, it is difficult to obtain significant results, and therefore, future studies will need to be done to study the effects of GraphoLearn English with a larger sample. The lack of significant effects may also be partially due to the short playtime. Participants in this study were non-native speakers of English and only had about 7.5 h of play time, as compared to 11 h in the study done by Kyle and colleagues with native speakers of English (Kyle et al., 2013). Due to the structure of the game, only about 60% of participants reached till stream eight, where the explicit practice of all rime units and their accompanying whole words begin. Further studies are required to determine if greater play time will produce significant effects on the GraphoLearn rime units and word recognition tasks.

Paper-pencil measures of reading and spelling were conducted to determine if there was a transfer of skills learned in-game to a non-game assessment. Although effect sizes of the gains were medium for the non-words and spelling tasks, confidence intervals of the effect sizes crossed zero and reflects insignificant group differences. Due to a lack of availiable measures standardized against such populations, we used measures which were designed for native English speaking children. Unfortunately, however, this created a less than ideal testing situation as the tasks were also quite far from what the game explicitly taught. In addition, given the fact that none of the participants had enough time to finish the game, there were many items (e.g., complex GPC's such as "the rule of *e*") that participants were not exposed to and therefore, were not able to learn from the game but were required on the paper-pencil measures. Like the in-game assessments, further studies will be required to determine if longer exposure to the game will produce transferable skills. It is also important that future studies use measures which are standardized to such populations.

Overall, the intervention opened the doors for GraphoLearn to be a potential success in the Indian context where the importance of English grows, yet supports for learning the language are lacking for many. We are hopeful that future studies using a larger sample, greater play time, and more effective measures will allow GraphoLearn to be comparable with the few interventions studies that have been done using phonics programs in the Indian setting (e.g., Nag-Arulmani et al., 2003; Dixon et al., 2011), with comparatively less demand of resources. GraphoLearn, as an tool, works by combining successful aspects of previous interventions, while providing individualized learning for students and easy to access data for teachers, factors crucial for implementation and success in a country like India (Central Square Foundation, 2015; Muralidharan et al., 2017). Generalizability of these results will be of question and therefore, it is important that going forward, further testing be done to determine if results improve when the GraphoLearn is used over a longer period of time, with a larger population, and in other parts of India where demands may differ. Nonetheless, this study provides a good first step in looking at how technology, and in particular GraphoLearn, can be used to support the English reading skills of struggling readers in India.

Limitations

There are a few limitations that must be taken into consideration when evaluating the results of this study. As mentioned, one major limitation was a small sample size. With a sample size of only 30 children, we were limited by the statistical approaches that could be used on the data, and understand that with a bigger sample, we would have had more statistical power. The small sample size also provided us with a limited capacity to control for unobserved variables, therefore, although we had random assignment, the methodological rigor of this random assignment can only be considered as "moderate." A second limitation was limited intervention time. Although the study was carried out over 8 weeks, the students only played for about 7.5 h. Most inability to play was due to student absenteeism and/or the school being unexpectedly closed. Due to limited play time, no student was able to complete all the streams. Although these factors limit the results of this study, such problems are very real for teachers in India. Therefore, what we see as limited may be what we would actually see if teachers were expected to carry out such and intervention themselves. Third, a methodological limitation that must be considered is the repeated exposure of the GraphoLearn group to the in-game assessments. As previously mentioned, GraphoLearn is built in a way so that students are exposed to an assessment stream after every four practice streams. Thus, students who played GraphoLearn has repeated exposure to the in-game assessments throughout the intervention period, whereas the control group was only exposed to the in-game assessments once at pre-test and once at post-test. This was unavoidable as the in-game measures were necessary to test the skills exactly as taught by the game. Also, using paper-pencil measures which were standardized for native English speakers, made them somewhat difficult for the participants of this study. In the future, this could be avoided by developing experimental measures which are standardized to this particular population. A fourth limitation from the point of view of practical implications was the full-time presence of a researcher during the intervention period. The presence of an adult who was fully focused on the participating children may have increased motivation. The researcher was also constantly supporting students by calling them if they were not in school and making it possible for them to play any time of the school day. In implementation of the game in everyday practices these conditions are not realistic. Similarly, we as researchers had access to a sufficient amount of equipment and resources (i.e., tablets and headphones, a working internet connection) in order for children to be able to play regularly. Going forward it is important that futures studies take into consideration the realities of implementation as to increase chances of sustainability (Central Square Foundation, 2015). Future studies could also study cost-effectiveness of GraphoLearn as an intervention tool in such localities. Finally, based on the current study, we do not know how the effects will be maintained over time. In future studies, it would be important to conduct follow-ups and determine whether or not effects are maintained by students even post-intervention. Going forward, it would also be important to use assessments which are normed for Indian students as to get more accurate results.

Practical Implications

The current study sheds insight into the ability of computer-assisted reading tools, like GraphoLearn, to support children who struggle to read in India. A logical next step would be to test GraphoLearn English on a larger scale over a longer period. As mentioned previously, the exposure time of students to the game was quite limited due to many uncontrollable factors. Thus, future studies should focus on exposure over a longer duration to determine whether that boosts effects and leads to students being able to transfer the skills they learn in the game to real life situations.

GraphoLearn also opens doors to the ability to provide interventions in children's mother tongue and other native languages. According to the 2001 census, 41% or more than 422 million individuals in India are Hindi speakers. Despite the large number of speakers, there is still a great need for ed-tech developers to cater to students who are studying in a native language in India (Central Square Foundation, 2015).

By now it has become clear that technology has potential to enhance learning, particularly in developing countries where differentiation is necessary, but difficult for a teacher alone to achieve (Muralidharan et al., 2017). However, there are still critical considerations that must be taken into account prior to implementing technology in schools. According to The World Bank (2018), technology should be used as a complement to teachers rather than a replacement for teachers. A study in India where children were provided technology as a teacher substitute within the school versus a teacher compliment out of school showed that children in the within school group learned significantly less (Linden, 2008). As suggested by Muralidharan et al. (2017), it may be most efficient if technology is used to create what they call a "blended learning" environment in which teachers use the information that they can gather from the technology to guide further instruction. In the current study, GraphoLearn was used as an in-school intervention which was meant to supplement teacher instruction. However, because teachers were not using phonics methods to teach English, there was no teacher involvement and therefore it became an isolated activity that the children performed during the day. In a previous study which looked at the effectiveness of GraphoLearn in Zambia, it was shown that an intervention design in which both students and teachers were trained on and played GraphoLearn lead to the greatest improvements in student learning (Jere-Folotiya et al., 2014). Thus, it must be considered how the technology can be used in greater collaboration with teachers as well.

GraphoLearn could provide teachers in India with an alternative to the currently used "rote-memorization" approach, and further increase the use of phonics as a method to teach English literacy in India.

AUTHOR CONTRIBUTIONS

PP performed this study as part of her master's thesis (Patel, 2018). She collected the data and is the main author of the paper. MT supervised PP in her master's thesis and supported planning of data collection, data analysis, and writing of the paper. MA provided guidance on the writing and proofreading of the paper. UR and HL provided their expertise on the details of the GraphoLearn software, as well as supporting the writing and proofreading of the paper.

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REFERENCES

Annamalai, E. (2004). "Medium of power: the question of English education in India," in *Medium of Instruction Policies: Which Agenda? Whose Agenda*, eds J. W. Tollefson and A. B. M. Tsui (Mahwah, NJ: Lawrence Erlbaum Associates), 177–193.

ASER (2016). *Annual Status of Education Report (Rural) 2016*. New Delhi: ASER Center.

Banerjee, A., Cole, S., Duflo, E., and Linden, L. (2007). Remedying education: evidence from two randomized experiments in India. *Q. J. Econ.* 122, 1235–1264. doi: 10.1162/qjec.122.3.1235

Central Square Foundation (2015). *The EdTech Promise: Catalysing Quality School Education at Scale*. Available at: http://www.centralsquarefoundation.org/wp-content/uploads/2015/11/The-EdTech-Promise-Catalysing-Quality-School-Education-at-Scale.pdf

Cheney, G., Ruzzi, B. B., and Muralidharan, K. (2005). *India Education Profile*. Washington, DC: National Center for Education and the Economy.

Chiappe, P., and Siegel, L. S. (1999). Phonological awareness and reading acquisition in English-and Punjabi- speaking Canadian children. *J. Educ. Psychol.* 91, 20–28. doi: 10.1037/00220663.91.1.20

Christensen, C. A., and Bowey, J. A. (2005). The efficacy of orthographic rime, grapheme-phoneme correspondence, and implicit phonics approaches to teaching decoding skills. *Sci. Stud. Read.* 9, 327–349. doi: 10.1207/s1532799xssr0904_1

Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences*, 2nd Edn. Hillsdale, NJ: Lawrence Earlbaum Associates.

Dixon, P., Schagen, I., and Seedhouse, P. (2011). The impact of an intervention on children's reading and spelling ability in low-income schools in India. *Sch. Effect. Sch. Improv.* 22, 461–482. doi: 10.1080/09243453.2011.625125

Ehri, L. C. (1998). "Grapheme-phoneme knowledge is essential for learning to read words in English," in *Word Recognition in Beginning Literacy*, eds J. Metsala and L. Ehri (Mahwah, NJ: Erlbaum), 3–40.

Ehri, L. C. (2005). Learning to read words: theory, findings, and issues. *Sci. Stud. Read.* 9, 167–188. doi: 10.1207/s1532799xssr0902_4

Ehri, L. C., Nunes, S. R., Stahl, S. A., and Willows, D. M. (2001). Systematic phonics instruction helps students learn to read: evidence from the National Reading Panel's meta-analysis. *Rev. Educ. Res.* 71, 393–447. doi: 10.3102/00346543071003393

Elliot, C. D., Smith, P., and McCulloch, K. (1996). *British Ability Scales II (BAS II)*. Windsor, VA: NFER-NELSON.

Goswami, U. (1986). Children's use of analogy in learning to read: a developmental study. *J. Exp. Child Psychol.* 42, 73–83. doi: 10.1016/0022-0965(86)90016-0

Goswami, U. (1988). Orthographic analogies and reading development. *Q. J. Exp. Psychol.* 40A, 239–268. doi: 10.1080/02724988843000113

Goswami, U., and Bryant, P. (1990). *Phonological Skills and Learning to Read*. Hillsdale, NJ: Erlbaum.

Haskell, D. W., Foorman, B. R., and Swank, P. R. (1992). Effects of three orthographic/phonological units on first-grade reading. *Rem. Spec. Educ.* 13, 40–49. doi: 10.1177/074193259201300207

He, F., Linden, L. L., and MacLeod, M. (2008). *How to Teach English in India: Testing the Relative Productivity of Instructional Methods Within the Pratham English Language Education Program*. New York, NY: Columbia University. Available at: https://www.povertyactionlab.org/sites/default/files/publications/153_318_How%20to%20teach%20English_He_Linden_Macleod_%20July2008_0.pdf

Hulme, C., Bowyer-Crane, C., Carroll, J. M., Duff, F. J., and Snowling, M. J. (2012). The causal role of phoneme awareness and letter-sound knowledge in learning to read: combining intervention studies with mediation analyses. *Psychol. Sci.* 23, 572–577. doi: 10.1177/0956797611435921

Hulme, C., Hatcher, P. J., Nation, K., Brown, A., Adams, J., and Stuart, G. (2002). Phoneme awareness is a better predictor of early reading skill than onset-rime awareness. *J. Exp. Child Psychol.* 82, 2–28. doi: 10.1006/jecp.2002.2670

Jere-Folotiya, J., Chansa-Kabali, T., Munachaka, J. C., Sampa, F., Yalukanda, C., Westerholm, J., et al. (2014). The effect of using a mobile literacy game to improve literacy levels of grade one students in Zambian schools. *Educ. Technol. Res.* 62, 417–436. doi: 10.1007/s11423-014-9342-9

Johnston, R., and Watson, J. (2005). *The Effects of Synthetic Phonics Teaching on Reading and Spelling Attainment: A Seven Year Longitudinal Study*. Available at: http://www.gov.scot/Publications/2005/02/20688/52449

Juel, C., and Minden-Cupp, C. (2000). Learning to read words: linguistic units and instructional strategies. *Read. Res. Q.* 35, 458–492. doi: 10.1598/RRQ.35.4.2

Kaila, V., and Reese, R. (2009). Relations between Indian children's home literacy environment and their English oral language and literacy skills. *Sci. Stud. Read.* 13, 122–145. doi: 10.1080/10888430902769517

Kingdon, G. G. (2007). The progress of school education in India. *Oxford Rev. Econ. Pol.* 23, 168–195. doi: 10.1093/icb/grm015

Kyle, F., Kujala, J., Richardson, U., Lyytinen, H., and Goswami, U. (2013). Assessing the effectiveness of two theoretically motivated computer assisted reading interventions in the United Kingdom: GG Rime and GG Phoneme. *Read. Res. Q.* 48, 61–76. doi: 10.1002/rrq.038

Lesaux, N. K., and Siegel, L. S. (2003). The development of reading in children who speak English as a second language. *Dev. Psychol.* 39, 1005–1019. doi: 10.1037/0012-1649.39.6.1005

Levy, B. A., and Lysynchuk, L. (1997). Beginning word recognition: benefits of training by segmentation and whole words methods. *Sci. Stud. Read.* 1, 359–387. doi: 10.1207/s1532799xssr0104_4

Linden, L. (2008). *Complement or Substitute? The Effect of Technology on Student Achievement in India*. Washington, DC: World Bank.

Lyytinen, H., Erskine, J., Kujala, J., Ojanen, E., and Richardson, U. (2009). In search of a science-based application: a learning tool for reading acquisition. *Scand. J. Psychol.* 50, 668–675. doi: 10.1111/j.1467-9450.2009.00791.x

Lyytinen, H., Ronimus, M., Alanko, A., Poikkeus, A., and Taanila, M. (2007). Early identification of dyslexia and the use of computer game-based practice to support reading acquisition. *Nord. Psychol.* 59, 109–126. doi: 10.1027/1901-2276.59.2.109

Mehrotra, R. R. (1998). *Indian English: Texts and Interpretation*. Amsterdam: John Benjamins Publishing Company. doi: 10.1075/veaw.t7

Mishra, R., and Stainthorp, R. (2007). The relationship between phonological awareness and word reading accuracy in Oriya and English: a study of Oriya-speaking fifth-graders. *J. Res. Read.* 30, 23–37. doi: 10.1111/j.1467-9817.2006.00326.x

Mitra, S., Tooley, J., Inamdar, P., and Dixon, P. (2003). Improving English pronunciation: an automated instructional approach. *Inf. Technol. Int. Dev. Dev.* 1, 75–84. doi: 10.1162/itid.2003.1.1.75

Muralidharan, K., Singh, A., and Ganimian, A. J. (2017). *Disrupting Education? Experimental Evidence on Technology-Aided Instruction in India.* Cambridge, MA: National Bureau of Economic Research.

Muter, V., and Diethelm, K. (2001). The contribution of phonological skills and letter knowledge to early reading development in a multilingual population. *Lang. Learn.* 51, 187–219. doi: 10.1111/1467-9922.00153

Nag, S. (2013). Low literacy attainments in school and approaches to diagnosis: an exploratory study. *Contemp. Educ. Dialog.* 10, 197–221. doi: 10.1177/0973184913484997

Nag-Arulmani, S., Reddy, V., and Buckley, S. (2003). Targeting phonological representations can help in the early stages of reading in a non-dominant language. *J. Res. Read.* 26, 49–68. doi: 10.1111/1467-9817.261005

NCERT (2014). *National Achievement Survey (Cycle 3), Class III: Achievement highlights*. New Delhi: National Council of Educational Research and Training.

NCERT (2015). *What Students of Class V Know and Can Do: A summary of India's National Achievement Survey, Class V, Cycle 4*. New Delhi: National Council of Educational Research and Training.

Ojanen, E., Ronimus, M., Ahonen, T., Chansa-Kabali, T., February, P., Jere-Folotiya, J., et al. (2015). GraphoGame-a catalyst for multi-level promotion of literacy in diverse contexts. *Front. Psychol.* 6:671. doi: 10.3389/fpsyg.2015.00671

Patel, P. (2018). *GraphoLearn India: The Effectiveness of a Computer-Assisted Reading Intervention in Supporting Struggling Readers in India*. Master's thesis, University of Jyväskylä, Jyväskylä, FI.

Richardson, U., and Lyytinen, H. (2014). The GraphoGame method: the theoretical and methodological background of the technology-enhanced learning environment for learning to read. *Hum. Technol.* 10, 39–60. doi: 10.17011/ht/urn.201405281859

Ruiz, J.-P., Lassault, J., Sprenger-Charolles, L., Richardson, U., Lyytinen, H., and Ziegler, J. C. (2017). GraphoGame: un outil numerique pour enfant en difficultes d'apprentissage de la lecture. *ANAE Approche Neuropsychologique des Apprentissages chez l'Enfant.* 148, 333–343.

Saine, N. L., Lerkkanen, M., Ahonen, T., Tolvanen, A., and Lyytinen, H. (2011). Computer-assisted remedial reading intervention for school beginners at risk for reading disability. *Child Dev.* 82, 1013–1028. doi: 10.1111/j.1467-8624.2011.01580.x

Seymour, P. H., Aro, M., and Erskine, J. M. (2003). Foundation literacy acquisition in European orthographies. *Br. J. Psychol.* 94, 143–174. doi: 10.1348/000712603321661859

Seymour, P. H. K., and Duncan, L. G. (1997). Small versus large unit theories of reading acquisition. *Dyslexia* 3, 125–134. doi: 10.1002/(SICI)1099-0909(199709)3:3<125::AID-DYS85>3.0.CO;2-4

Stuart, M. (1999). Getting ready for reading: early phoneme awareness and phonics teaching improves reading and spelling in inner-city second language learners. *Br. J. Educ. Psychol.* 69, 587–605. doi: 10.1348/000709999157914

Stuart, M. (2004). Getting ready for reading: a follow-up study of inner city second language learners at the end of Key Stage 1. *Br. J. Educ. Psychol.* 74, 15–36. doi: 10.1348/000709904322848806

Tamim, R. M., Bernard, R. M., Borokhovski, E., Abrami, P. C., and Schmid, R. F. (2011). What forty years of research says about the impact of technology on learning: a second-order meta-analysis and validation study. *Rev. Educ. Res.* 81, 4–28. doi: 10.3102/0034654310393361

Tanna, N. (2009). Test review: word reading efficiency. *J. Occup. Psychol. Empl. Disabil.* 11, 45–48.

The World Bank (2011). *Poverty and Equity Data Portal*. Available at: http://povertydata.worldbank.org/poverty/country/IND

The World Bank (2012). *India's Poverty Profile*. Available at: http://www.worldbank.org/en/news/infographic/2016/05/27/india-s-poverty-profile

The World Bank (2018). *World Development Report 2018: Learning to Realize Education's Promise*. Washington, DC: World Bank doi: 10.1596/978-1-4648-1096-1

Thomson, M. (1997). "Test review," in *The Psychological Assessment of Reading*, eds J. R. Beech and C. Singleton (London: Routledge), 297–298.

Tooley, J., and Dixon, P. (2005). *Private Education is Good for the Poor: A Study of Private Schools Serving the Poor in Low-Income Countries*. Washington DC: Cato Institute.

Torgesen, J. K., Wagner, R. K., and Rashotte, C. A. (1999). *Test of Word Reading Efficiency*. Austin, TX: Pro-Ed.

UNESCO (2015). *India*. Available at: http://uis.unesco.org/country/IN

Wyse, D., and Goswami, U. (2008). Synthetic phonics and the teaching of reading. *Brit. Educ. Res. J.* 34, 691–710. doi: 10.1080/01411920802268912

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II

ASSESSING THE EFFECTIVENESS OF A GAME-BASED PHONICS INTERVENTION FOR FIRST AND SECOND GRADE ENGLISH LANGUAGE LEARNERS IN INDIA: A RANDOMIZED CONTROLLED TRIAL

by

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ARTICLE

Assessing the effectiveness of a game-based phonics intervention for first and second grade English language learners in India: A randomized controlled trial

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Abstract

Background: In 2018, it was found that only a quarter of Grade 3 children in India were reading at grade level. A growing demand for English education has further limited children's literacy achievement. Despite a strong evidence base in favour of using systematic phonics for building English literacy skills, many teachers in India continue to use rote-methods of literacy instruction.

Objectives: We aimed to examine the efficacy of GraphoLearn (GL) English Rime, a computer-assisted reading intervention, in improving the foundational literacy skills of 1st and 2nd grade students who were attending an English medium school in India.

Methods: A total of 136 students across 6 classrooms were randomly allocated to play either GL or a control math game over a 5-week intervention period. Students were pre- and post-tested on various English literacy skills using tasks built into the GL software as well as through oral and paper-based tasks.

Results and Conclusions: Students who played GL showed significantly greater and faster development on in-game measures of letter-sound knowledge, rime unit recognition, and word recognition as compared to students who did not play GL. In addition, GL resulted in greater effects on these measures for students with stronger English literacy skills prior to the start of the intervention. No differences were found between groups on the oral and paper-based tasks.

Implications: GL was able to quickly and effectively teach critical sub-skills for reading. However, a lack of effects on the out-of-game measures opens the door for further discussion on the successful implementation of such interventions.

KEYWORDS
educational technology, English language learners, GraphoLearn, India, intervention, phonics

1 | INTRODUCTION

Today, the importance of the ability to read is largely uncontested. Failure to acquire functional literacy skills is known to have adverse and long-lasting individual and societal effects. Nevertheless, a global learning crisis persists with many children, particularly those in low-income countries, lacking basic reading skills (The World Bank, 2018). India is home to over 200 million school-going children. However, poor quality schools have resulted in consistently low learning levels across the country (Banerjee et al., 2007). In 2018, for instance, it was found that only 27% of Grade 3 students in India were reading at grade-level (ASER, 2018).

Researchers have identified a multitude of factors believed to be contributing to such statistics. A lack of quality early childhood educational opportunities means that many children enter primary school lacking foundational skills identified as critical for school-readiness (ASER, 2019). Upon entry into primary school, children are often faced with textbooks and curricula which fail to take into consideration their existing learning levels (see Pritchett & Beatty, 2012). In addition, a highly multilingual society with ever increasing pressures to learn English means that many children attend school in a foreign language (Graddol, 2010). Lofty expectations on behalf of policy makers, school administration, and society, coupled with outdated pedagogical practices, ultimately results in a situation where many children fall behind early on and are never able to catch up (MHRD, 2019).

Computer-assisted learning programs, particularly in the form of serious games, are growing in popularity around the world to help support student learning. A notably appealing feature of such games is that they allow for a greater personalization of learning; content and levels of difficulty can be designed so that it adapts to the needs of the player allowing for more effective practice. This type of technology-supported personalized learning has been found to show promise for improving learning outcomes, particularly in low and middle-income countries (see Major & Francis, 2020 for review). India has a booming educational technology sector, but there are still many barriers to the effective implementation of technology in schools (Byker, 2014). Furthermore, a lack of efficacy studies in the context of India have made it difficult to identify which types of technologies work best, when, and with whom (Miglani & Burch, 2019). In the present study we aimed to test the efficacy of GraphoLearn English Rime (GL), an empirically validated technology-based reading intervention with first and second grade English language learners (ELLs), in India.

1.1 | Early reading skills and ELLs

Fundamental to learning to read in an alphabetic language, such as English, is the acquisition of the alphabetic principle, an understanding of how symbols of the written language (graphemes) represent sounds in the spoken language (phonemes; Castles et al., 2018). Letter knowledge, which includes the understanding of both letter-sounds and letter-names, and phonological awareness have been identified as foundational skills underlying this alphabetic insight (Byrne, 1998; Byrne & Fielding-Barnsley, 1989). Many studies have found letter-name knowledge to be a powerful predictor of reading achievement, particularly in the early grades (see Foulin, 2005 for review). It acts as a scaffold for learning letter-sounds, a critical skill which aids in the ability to decode unfamiliar words (Huang et al., 2014). In addition, phonological awareness skills, in particular phonemic awareness, the ability to identify and manipulate sounds (phonemes) in spoken words, is essential in helping early readers further connect speech to print (Ehri & Roberts, 2006). In a meta-analysis conducted by Melby-Lervåg et al. (2012), phonemic awareness was found to be one of the strongest correlates of differences in children's word reading ability.

Research examining ELLs and L1 English speakers has indicated that English word reading development occurs along a similar trajectory in both groups. Muter and Diethelm (2001) studied Kindergarten children from multilingual backgrounds who were attending school in English. While language measures such as English vocabulary differentiated L1 English and ELLs, phonological awareness measures did not. Furthermore, English phonological awareness, particularly phonological segmentation ability, and letter knowledge were found to be significant predictors of English reading skills, both concurrently and a year later for both groups.

Similar findings have also emerged when researchers have studied children from Indian L1 backgrounds. Chiappe and Siegel (1999) studied Grade 1 children from Punjabi-speaking homes who were studying in English while living in Canada. They too found that there was little difference in the performance profiles of L1 English and L1 Punjabi children who were learning to read in English. No significant differences were found between the two groups on measures of English phonological processing and word recognition. In addition, both groups relied on using letter-sound correspondences when reading unfamiliar words, and in both groups, those who struggled were less skilled at applying this knowledge. While studies on the reading development of ELLs in India are limited, a recent examination of the reading profiles of children across Grades 1–5 who were learning English as a second literacy language in India revealed phoneme awareness to be a strong predictor of English reading skills (Nakamura & De Hoop, 2014). Phonological awareness and letter knowledge play a significant role in English reading ability, for both L1 English and ELL children. Pedagogically, this opens the door to the possibility of using methods to support these skills for both native and non-native English speakers, as they may be equally valid for both groups of children (Muter & Diethelm, 2001).

1.2 | The role of phonics

Longitudinal studies examining the developmental trajectories of reading and spelling have shown that ELLs who may be behind are able to catch up if they receive adequate literacy exposure and instruction (Lesaux et al., 2007). Systematic phonics, in which children are explicitly taught letter-sound (grapheme-phoneme) correspondences, has repeatedly been identified as the most effective approach to helping children acquire knowledge of the alphabetic principle and to use this knowledge in decoding unknown words (Castles et al., 2018; Ehri, 2003). A notable review on the efficacy of systematic phonics instruction, conducted by the National Reading Panel in the United States, showed a moderate effect ($d = 0.41$) of phonics-based instruction as compared to various other forms of instruction, such as whole-word (Ehri, 2003). In addition, the effect of phonics-based instruction was found to be stronger ($d = 0.55$) when instruction was received early rather than after Grade 1 ($d = 0.27$). The positive effects of systematic phonics instruction have similarly been extended to English language learners (Stuart, 1999).

The small number of studies examining the efficacy of phonics-based methods for teaching English to children in India have thus far been highly promising. Dixon et al. (2011) tested the efficacy of Jolly Phonics intervention as compared to regular classroom instruction, with children attending an English-medium, low-income private school in Hyderabad, India. Within each school, Grade 1 students were given Jolly Phonics intervention for an hour a day, 5 days a week, over a period of 6 months as compared to business-as-usual instruction. Results showed a statistically significant difference between the groups, with the Jolly Phonics group performing better on tasks of reading, spelling, and sounding out letters and words, leading authors to conclude that phonics-based methods are effective for teaching English to children in India, even to those who are first-generation ELLs.

A second study examined the effects of phonics-based English instruction when used with economically disadvantaged Grade 5 children who were attending Kannada-medium school, but who had been learning English as an additional language starting from Grade 3 (Nishanimut et al., 2013). The intervention group received a conventional synthetic phonics intervention for an hour per day while the control group continued to learn English through rote learning of their textbooks. After a 5-week intervention period, those who received phonics-based instruction performed significantly better than the comparison group on measures of letter naming, word reading, non-word reading, and multiple measures of grapho-phonological awareness. The study provided further evidence for the efficacy of phonics instruction, even for those students who are not studying in English-medium school but who are learning English as an additional language. While studies for the use of phonics in the Indian classroom have shown promise, phonics has yet to find a permanent place in the Indian classroom.

1.3 | English literacy instruction in India

Given India's multicultural landscape, it is not uncommon for individuals to use a variety of languages in everyday life. English plays a critical role in India's education system as one of the two official languages of the country (NCERT, 2005), and also plays an important societal role as a language of opportunity (Annamalai, 2004). Consequently, parents from all backgrounds are increasingly choosing to educate their children in schools where English is the primary medium of instruction. As of 2015, 29 million children are believed to be enrolled in English medium schools across India (Nagarajan, 2015) and it is estimated that 25% of children in these schools are first generation ELLs (Graddol, 2010).

It has become clear that while English medium schools are highly desirable, enrolment has not equated to learning. The 2016 Annual Status of Education Report, which specifically examined English literacy in India, showed that 53% of Grade 1 students were unable to identify capital letters, and only 15% of Grade 2 and 20% of Grade 3 students were able to read simple words such as ‘fan’ (ASER, 2016). A 2012 study on the teaching of English in public primary schools highlighted the many factors contributing to low reading achievement in India, including the predominate focus on rote-reading and copy writing (Dutta & Bala, 2012).

In most Indian public schools, English word reading is taught in a similar fashion to what Rayner et al. (2001) describe as the ABC method (also known as the alphabet-spelling method; see Gupta, 2014), in which children are taught letter names which are then used to spell words (e.g. ‘double-you-ay-ell-ell is wall’). Common words are taught through sight and most reading in the classroom is done aloud by the teacher (Dutta & Bala, 2012). While phonics-based instruction has been recommended, there is limited evidence of sustained implementation. Gupta (2014) conducted a study observing phonics instruction in two schools in South India where teachers themselves had learned through the alphabet-spelling method. It was seen that when teachers intended to use phonics, instruction on letter-sounds halted after one sound for each of the 26 letters was taught and teachers continued to articulate individual letter-sounds rather than teaching children how to blend together sounds to decode words (e.g., /k/ /l/ /o/ /ə/ /d/ is cloud; Gupta, 2014). In a study examining factors which influence second-language English reading in India it was found that Grade 1 students in economically disadvantaged areas struggled with English decoding and failed to acquire reading skills even by Grade 5; a finding which was attributed to the lack of phonics-based instruction (Shenoy et al., 2020).

1.4 | GraphoLearn

GraphoLearn (GL; formerly known as GraphoGame), is a globally studied computer-assisted reading intervention which uses systematic phonics to train the connections between spoken and written language (Lyytinen et al., 2009; Lyytinen et al., 2021; Richardson & Lyytinen, 2014). Numerous studies have provided evidence for the explicit training of phonological skills and letter-sound linkages in helping poor readers develop understanding of the alphabetic principle (see Hatcher et al., 1994, 2004), even for ELLs (Stuart, 1999). GL promotes these skills using adaptive technology, allowing for individualized practice. Implemented in more than 20 countries across various languages, there is a growing evidence base for the use of GL around the globe (Lyytinen et al., 2021; McTigue et al., 2019).

In this study we used GL English Rime, a version of GL which uses systematic rhyme family groupings, where a small number of individual letter-sound (grapheme-phoneme) correspondences are introduced,

FIGURE 1 Example of a letter-sound game screen from GL English Rime. Players hear a speech-sound and are required to select the correct written form out of the options provided. The number of options increases as players advance within the game

after which they are combined to form larger and more consistent orthographic rime units, and finally words (see Kyle et al., 2013). The game consists of 25 play streams and 7 assessment streams, each with multiple levels, in which the content is organized so that the largest rhyme families with the most consistent orthographic rime spellings are introduced first. Within each level, players hear a speech sound which they are then required to match with the correct written unit from the multiple options presented on the screen (see Figure 1). Phonological awareness skills are further trained through rhyme awareness tasks and spelling skills are supported through word formation tasks in which players drag letter tiles into the correct order to spell a given word. If players make an incorrect selection, they are provided with feedback which guides them to the correct selection. Players are required to achieve 80% accuracy across the levels within a given stream to unlock the next stream. To aid in motivation, rewards are provided throughout the game in the form of stars and coins. For research purposes, data from the game is automatically saved to an external server when players quit their play session so long as the device has an active internet connection.

A review of findings across 28 GL studies highlighted that the effectiveness of GL varies across languages and educational contexts (McTigue et al., 2019). In this study, we specifically evaluated the effectiveness of the English Rime version of GL. The first study utilizing GL English Rime was conducted by Kyle et al. (2013) in which GL English Rime was compared to both, a phoneme-based version of GL which focuses on only instructing individual letter-sound correspondences (vs. coupled with rime units) and an untreated control group. Both game versions were found to be effective in comparison to the control group, and no significant differences were found in the effect sizes of the gains between the two game versions. When the GL Rime group was compared to the untreated controls, large effects were found on the gain scores for tasks of word reading, non-word reading, and spelling. Bhide et al. (2013) conducted a study in which the effects of GL Rime were compared to a musical intervention. The GL group showed large effects on decoding and spelling, however, there were no significant differences between the groups indicating that both interventions benefited struggling readers.

Based on these two small-scale pilots, a large-scale randomized controlled trial study of GL Rime was conducted (Worth et al., 2018) with almost 400 Grade 2 students across the UK. Teachers found GL Rime easy to implement, engaging, and motivating, however, there was no evidence of improved reading outcomes over business-as-usual instruction. Due to the large sample size, there was great variation in how long children played GL and how far they progressed in the game. A reanalysis of this sample was conducted by Ahmed et al. (2020), in which they specifically examined only those children who reached above the group mean in play progress, or what they refer to as the 'top half' of players. When these children were compared to the full sample of control children, those in the GL group showed significantly higher gains and it was concluded that GL is more effective than business-as-usual in developing English phonics (Ahmed et al., 2020). Wilson et al. (2021) recently re-examined the same data set to better understand the types of children who best respond to GL intervention as indicated by game progress. They found that phonological skills and executive functioning skills were the strongest unique predictors of game progress. Interestingly, vocabulary was not a significant predictor indicating that even those with limited English vocabulary are able to benefit from playing GL English Rime.

Findings from these studies are highly informative given that GL has been found to be just as effective as business-as usual literacy instruction, at least in the UK (Worth et al., 2018). When it works, technology-led instruction can benefit children's learning (see Banerjee et al., 2007), often in a time and cost-effective manner (Muralidharan et al., 2019). Often, however, technology-led solutions developed in high-income contexts are 'copy-pasted' into more challenging environments such as those in low-income countries where resources are strained and knowledge is limited, and as a result, they may not work as effectively (Trucano, 2014). Therefore, it is critical that efficacy studies of educational technologies are conducted in various environments to help us untangle what works, for whom, and when (Trucano, 2005).

Currently, there is limited evidence on the efficacy of GL English Rime in places such as the Global South. One study which examined GL English Rime intervention as compared to phoneme and word-level interventions in Singaporean schools found that all three interventions led to increased reading outcomes but there were no significant differences between the three interventions (O'Brien et al., 2019). Unfortunately, however, this study did not contain a no-intervention control group. An extensive amount of GL research has also been done in sub-Saharan Africa where children are learning to read in a multilingual context and are faced with many of the same challenges as students in India. While these studies have not utilized GL English Rime, results from studies implementing other versions of GL in Africa have been highly promising (see Lyytinen et al., 2019 for review). We believe that it is worthwhile to extend the existing evidence base around the efficacy of GL English to include India, a country housing a large portion of the world's student population who are failing to acquire literacy skills.

1.5 | The present study

In this study, we aimed to examine whether GL English Rime could be used as an effective intervention to improve the foundational literacy skills of children learning to read English in India. The present study is an extension of a former small-scale pilot study, the first of its kind to examine GL in India. Grade 3 ELLs in an English-medium public school in Ahmedabad, India were randomly allocated to play either GL English Rime or a control math game as a supplement during school (Patel et al., 2018). Results indicated that those who received GL intervention showed significant gains in letter-sound knowledge after an 8-week intervention period. While these results were promising, the authors found no evidence of a transfer of learning to paper-based tasks of reading and spelling.

This pilot study had some notable limitations, which we believe may help to explain the pattern of results. Along with a small sample size, the study was conducted with Grade 3 children. Meta-analyses have shown a greater overall effect of phonics interventions when used with younger children (i.e. Kindergarten-Grade 1; $d = 0.55$) versus older children (i.e. Grade 2–6; $d = 0.27$; Ehri, 2003). Thus, we aimed to replicate the study with a younger sample of students. We also included a wider range of oral and paper-based assessments and selected assessments which were specifically developed and validated for use on children in India. Our research questions were as follows:

1. Do children who play GL significantly outperform children who do not on game-based measures of English reading skills?
2. Do children who play GL significantly outperform children who do not on oral and paper-based measures of English reading skills?
3. How does progress within GL relate to students' pre-test, post-test, and gain scores? Are there differences in effectiveness based on this relation?

2 | MATERIALS AND METHODS

2.1 | Participants

The data reported is from 136 students across three Grade 1 classrooms and three Grade 2 classrooms from one public school in Delhi, India. The students were an average of 6.2 years old (range = 5–7 years) at the start of the study which began approximately 6 months into the school year. The primary medium of instruction was English but students learned Hindi, the regional language in Delhi, as an additional language for one period per day. Student demographics, for each condition, including age, gender, grade level, and language used at home are described in Table 1.

Prior to the start of the study, the students' parents were invited to the school and taken through the consent form which was provided to them in both English and Hindi to ensure they were fully informed. In total, the parents of all 143 students consented and all participated in the study. However, data from seven students has been excluded from the analysis due to dropping out of the study prior to post-testing or having GL data which failed to save to the server.

TABLE 1 Demographics

	GL ($n = 69$)		Control ($n = 67$)	
	n	%	*n*	%
Gender				
Male	35	51	34	51
Female	34	49	33	49
Grade				
1	33	48	31	46
2	36	52	36	54
Home Language				
Hindi	57	83	55	82
Hindi + English	9	13	9	14
Hindi + Other	3	4	1	2
Other	0	0	1	2

2.2 | Procedure

A matched pairs randomized design was used in which randomization was done within classrooms. Students within each classroom were matched on age and gender, and then randomly allocated to either the GL group ($n = 69$) or the control group ($n = 67$) which played a math game. Teachers were fully informed of the study but were asked to continue teaching their lessons as usual. Prior to the start of the intervention, students were pretested in a group format as well as individually. The individual sessions lasted approximately 30 minutes and all testing was conducted by the primary researcher along with trained research assistants who also facilitated the intervention. After the intervention was complete, post-testing was done using the same measures and by the same facilitators.

For the intervention sessions, 25 smartphones were set up in a spare classroom in the school and students were brought in class-by-class, 5 days a week, for 20 minute sessions during their regular school hours. The students in the intervention group played GL English Rime. Each student had a pre-created avatar which was labelled with their name to ensure that they played under the same profile for the entire duration of the intervention. The students in the control group played a math game called 'Math Kids- Add, Subtract, Count, and Learn', which was selected from the Google Play store. 'Math Kids' consists of mini games to practice basic counting and comparison skills, as well as basic arithmetic operations; skills the class teachers confirmed students were learning according to their curriculum. Like the GL group, each student in the control group had a profile labelled with their name under which they played. Although there was no pre-set order which the game required players to follow, the research team ensured that children were playing a different, often more difficult, level each week to maintain interest and motivation.

Although the game had very limited visual and auditory language input, the game language was changed to Hindi to ensure that any language exposure was not occurring in English. The purpose of the math game was to ensure that both groups of children were exposed to technology-based games and spent an equivalent amount of time away from classroom instruction.

Fidelity to the intervention was controlled by logs sent to the GL server which include days played and time spent playing. Students' attendance in the sessions was also recorded by the research team, and although students played their respective games independently, the primary researcher and research assistants supervised the play sessions. Upon completion of the intervention, there was no significant difference between the GL group ($M = 20.19$, $SD = 2.42$) and the control group ($M = 19.91$, $SD = 2.69$; $t(134) = 0.60$, $p = 0.55$), in the number of play sessions attended.

2.3 | Measures

Both groups were assessed at pre- and post-test using the GL in-game assessment which contains a letter-sounds task, a rime unit task, and a word recognition task (see Table 2 for detailed task descriptions). The children were brought in class-by-class into a spare classroom where the smartphones were set up. The game was introduced to them after which they were instructed to play the assessment levels. In the assessment levels, just as in the game levels, players are presented with an auditory target which they are required to match with a visual target out of the multiple options provided. The in-game assessment contains both trained and untrained items and not all of the trained content is in the assessments. The purpose of the in-game assessment tasks was to assess players' performance on skills explicitly instructed by the game (i.e., recognition) and in a manner similar to that in which they had learnt and practiced those skills (i.e., matching an auditory target to a visual target). The letter-sound knowledge task contains 24 trials and players are exposed to all trials regardless of performance. The rime units task contains 24 trials, and the word recognition task contains 47 trials; however, these tasks discontinue after the player answers more than 50% of the items incorrectly.

Oral and paper-based tasks were administered at pre- and post-test to give insight into existing literacy skills at pre-test and to determine if there is a transfer of learning to an out-of-game context at post-test. An important consideration for this study was the use of assessments which were designed and validated for use with children in India. Subtests from the English version of the Dyslexia Assessment for Languages of India (DALI; Rao et al., 2021; Singh, 2015), as well as tasks (PhAB) developed by Cherodath and Singh (2015) were used. Students were brought into a quiet room within the school and the tasks were administered one-on-one by the primary researcher along with trained research assistants. The spelling assessment was conducted as a whole class dictation administered either by the primary researcher or the research assistants. Detailed descriptions of the oral and paper-based tasks, scoring criteria, and their reliability are provided in Table 3.

TABLE 2 GL in-game task descriptions

Task	Description	Scoring
Letter sounds	Students were presented individual letter sounds auditorily which they had to match with the correct written form out of the multiple options presented to them	Total number of correct responses
Rime units	Rime units (i.e., -ip, -at) were presented auditorily which students were required to match with the correct written form out of the multiple options presented to them	Total number of correct responses
Word recognition	Words were presented auditorily which students were required to match with the correct written form out of the multiple options presented to them	Total number of correct responses

3 | RESULTS

The data was analysed using IBM SPSS Statistics. First the distributions of the raw scores of the in-game assessments and the oral and paper-based assessments were examined for normality. The in-game assessments contained outliers which resulted in slightly skewed distributions. For all three tasks, the scores were winzorized to meet the assumption of normality. Regarding the oral and paper-based measures, scores on the letter name identification ($M = 9.58$, $SD = 1.11$) and letter spelling ($M = 9.42$, $SD = 1.50$) measures were at ceiling at pre-test, consequently resulting in a negatively skewed distribution. Therefore, these two measures were not analysed further. All remaining oral and paper-based measures produced a normal distribution at both time points. In addition, the two English word reading lists were found to be highly correlated at both pre-test ($r = 0.87$) and post-test ($r = 0.89$), therefore, an average of the two scores was used for analysis.

To answer the first research question, the results from the GL in-game assessment tasks at pre- and post-test were explored (see Table 4). Repeated measures ANOVA was used to examine time × group interaction effects, as well as main effects of time and group. A significant time × group interaction effect was found for all three in-game assessment tasks, with the GL group showing significantly higher scores and faster development than the control group. Effect sizes (partial eta squared) of the interactions are

TABLE 3 Out-of-game oral and paper-based task descriptions

Task	Description	Scoring	Cronbach's α
Rhyme identification (DALI)	Two practice sets followed by 12 sets of three words were presented orally and students were required to identify the two words which rhymed	A score of one was given for every correctly identified pair	0.83
Phoneme replacement (DALI)	Two practice words followed by 10 words were presented orally in which students were asked to replace the initial phoneme with a given phoneme	A score of one was given for every correct replacement	0.89
Letter naming (DALI)	Student were asked to name 10-upper case letters presented to them on a sheet	A score of one was given for every correctly named letter	0.76
Semantic fluency (DALI)	Students were given 30 seconds each to name as many objects in two given categories—fruits and vegetables	The total number of correctly named items in each category were counted	–
Verbal fluency (DALI)	Students were given 30 seconds each to name as many words beginning with two given phonemes—/b/ and /m/	The total number of correctly named words in each category were counted	–
Word reading (DALI)	A set of 25 words which were collated from Grade 1 and 2 textbooks and arranged in order of increasing difficulty	A score of one was given for every correctly read item	0.94
Word reading (PhAB)	A set of 20 words collated from Grade 1–3 textbooks	A score of one was given for every correctly read item	0.94
Pseudoword reading (PhAB)	A set of 20 words in which a single letter in a real word was replaced to create a legally pronounceable string	A score of one was given for every correctly read item	0.91
Letter spelling (DALI)	10-item letter name dictation	A score of one was given for every correctly written letter	0.83
Spelling (DALI)	20-item word dictation consisting of words collated from Grade 1 and 2 textbooks, presented in order of increasing difficulty	A score of one was given for every correctly written word	0.90

TABLE 4 Descriptive statistics and group comparisons on GL in-game assessment tasks

		GL *M* (*SD*)	Range	Control *M* (*SD*)	Range	*t*	Group	Time	Interaction	Effect size η_p^2
Letter sounds	Pre	7.93 (2.93)	0–14	7.75 (2.28)	2–14	0.34	61.99***	210.04***	131.89***	0.50
	Post	17.61 (5.95)	4–41	8.97 (3.79)	2–26	11.11***				
Rime units	Pre	1.55 (1.83)	0–10	1.43 (1.69)	0–9	0.50	35.55***	69.43***	43.89***	0.25
	Post	7.26 (6.10)	0–21	2.12 (2.63)	0–15	6.67***				
Word recognition	Pre	3.41 (2.21)	0–8	3.16 (2.50)	0–14	0.74	5.56*	49.34***	7.86**	0.06
	Post	6.93 (6.99)	0–40	4.36 (3.08)	0–14	2.85**				

***$p < 0.001$. **$p < 0.01$. *$p < 0.05$.

reported in Table 4. The criteria as that defined by Cohen (1988) is being used in which $\eta_p^2 \geq 0.01$ is a small effect, $\eta_p^2 \geq 0.06$ is a medium effect, and $\eta_p^2 \geq 0.14$ is a large effect. In line with the significant interaction effects, a large effect was found for both the letter-sounds and rime unit tasks and a medium effect was found for the word recognition task. An independent samples *t*-test was then conducted to examine group differences at pre- and post-test across the three tasks, and results showed no significant group differences at pre-test, indicating equivalent groups. At post-test, significant group differences in favour of the GL group were found for all three tasks.

To answer the second research question, the results from the oral and paper-based tasks at pre- and post-test were explored (see Table 5). Results of a repeated measures ANOVA indicated no significant time × group interaction effects across all of the measures. A significant main effect for time was found, indicating development in both groups across all tasks, however, no significant main effect was found for group. Nevertheless, effect sizes of the interaction

TABLE 5 Descriptive statistics and group comparisons on out-of-game oral and paper-based tasks

		GL *M* (*SD*)	Range	Control *M* (*SD*)	Range	*t*	Group	Time	Interaction	Effect size η_p^2
Rhyme identification	Pre	4.84 (3.73)	0–12	5.31 (3.00)	0–11	−0.82	0.001	62.33***	3.76	0.03
	Post	7.30 (3.62)	0–12	6.81 (3.53)	0–12	0.81				
Phoneme replacement	Pre	4.19 (3.17)	0–10	4.36 (3.42)	0–10	−0.30	0.13	92.68***	2.56	0.02
	Post	6.65 (3.01)	0–10	6.12 (3.40)	0–10	0.97				
Semantic fluency	Pre	6.94 (3.64)	0–15	7.61 (3.54)	0–16	−1.09	0.48	24.27***	1.21	0.01
	Post	8.38 (3.49)	2–16	8.52 (4.09)	0–19	−0.22				
Verbal fluency	Pre	4.38 (3.49)	0–14	4.27 (3.27)	0–11	0.19	0.000	140.34***	0.23	0.002
	Post	6.83 (3.65)	0–17	6.93 (3.08)	0–12	−0.17				
Word reading	Pre	10.85 (6.66)	0–22.5	11.06 (6.36)	0–22	−0.19	0.01	176.36***	0.41	0.003
	Post	13.78 (6.76)	0–22.5	13.72 (6.73)	0–22.5	0.05				
Pseudoword reading	Pre	5.55 (5.38)	0–19	5.52 (5.41)	0–18	0.03	0.004	68.31***	0.01	0.000
	Post	8.54 (6.43)	0–20	8.45 (6.65)	0–20	0.08				
Spelling	Pre	9.43 (5.18)	0–20	9.66 (4.83)	0–19	−0.26	0.01	25.73***	0.36	0.003
	Post	10.74 (5.01)	0–20	10.68 (4.54)	0–18	0.06				

***$p < 0.001$.

TABLE 6 Game progress and assessment score correlations of the GL group

	Pre-test score	Post-test score	Gain score
In-game measures			
Letter sounds	0.56***	0.69***	0.41***
Rime units	0.33**	0.64***	0.58***
Word recognition	0.50***	0.70***	0.54***
Oral and paper-based measures			
Rhyme identification	0.55***	0.73***	0.20
Phoneme replacement	0.62***	0.67***	0.02
Semantic fluency	0.50***	0.64***	0.15
Verbal fluency	0.69***	0.68***	0.03
Word reading	0.79***	0.81***	0.10
Pseudoword reading	0.67***	0.76***	0.32**
Spelling	0.76***	0.82***	0.06

***$p < 0.001$. **$p < 0.01$.

suggested a small effect for rhyme identification, phoneme replacement, and semantic fluency. Results of an independent samples *t*-test showed no significant group differences at pre-test or post-test across the oral and paper-based measures.

In line with our third research question, we aimed to better understand individual differences in learning from the game by further examining the GL group ($n = 69$) and exploring the relationship between progress made by students in the game (i.e., highest stream reached out of 25) and their scores at pre- and post-test, as well as their gain scores. As previously mentioned, GL requires that players reach 80% mastery within a stream before allowing them to move on to the next stream. Therefore, we wanted to see which children were progressing in the game and whether children's progress in the game related to their performance on the assessment tasks. Stream data as recorded by the GL server was used for the analysis. Correlations between the highest stream reached and the pre-test, post-test, and gain scores across all the assessment tasks are reported in Table 6. A significant positive relationship was found between the highest stream reached in the game and students pre- and post-test scores across all measures, indicating that those who made it further in the game not only had higher post-test scores but also higher pre-test scores. A significant positive relationship was also found between the highest stream reached and the gains made for all the in-game measures as well as the pseudoword reading measure, indicating that those who completed more of the game also had greater in-game assessment gains and pseudoword reading gains.

TABLE 7 Descriptive statistics and group comparisons on the GL in-game assessment tasks for the bottom 50% and top 50%

		GL *M* (*SD*)	Control *M* (*SD*)	*t*	Group	Time	Interaction	Effect size η_p^2
Bottom 50%								
Letter sounds	Pre	6.56 (2.68)	6.31 (3.02)	0.36	28.96***	68.39***	48.17***	0.41
	Post	15.33 (7.22)	7.06 (2.61)	6.98***				
Rime units	Pre	0.89 (1.14)	0.80 (0.87)	0.37	12.96**	24.59***	13.74***	0.17
	Post	4.25 (4.38)	1.40 (1.87)	3.86***				
Word recognition	Pre	2.50 (1.83)	2.09 (1.87)	1.23	3.41	19.79***	1.09	0.02
	Post	4.25 (3.06)	3.09 (2.53)	1.75				
Top 50%								
Letter sounds	Pre	9.42 (2.45)	9.31 (2.83)	0.17	92.68***	181.37***	102.96***	0.62
	Post	20.09 (2.45)	11.06 (3.80)	13.79***				
Rime units	Pre	2.27 (2.16)	2.13 (2.08)	0.41	39.66***	57.20***	40.52***	0.39
	Post	10.55 (6.05)	2.91 (3.10)	6.86***				
Word recognition	Pre	4.39 (2.19)	4.34 (2.59)	0.26	5.24*	24.69***	6.87*	0.10
	Post	9.85 (8.76)	5.75 (3.06)	2.65*				

***$p < 0.001$. **$p < 0.01$. *$p < 0.05$.

Given these findings, we further explored whether there were differences in game effectiveness based on children's pre-test levels. To do this, a composite score was calculated of all of the pre-test measures (both GL in-game and oral and paper-based). The full sample was then divided using median splits resulting in two new groups, one with students who had English literacy skills in the top 50% at pre-test ($n = 33$ GL, $n = 32$ control) and one with students who had English literacy skills in the bottom 50% at pre-test ($n = 36$ GL, $n = 35$ control).

Pre- and post-test means, standard deviations, and group comparison results on the GL assessment tasks for the students grouped by pre-test performance are reported in Table 7. Repeated measures ANOVA was once again used to examine time × group interaction effects, as well as main effects of time and group across the GL assessment tasks for both the top 50% and bottom 50% (see Table 7). For the bottom 50%, a significant time × group interaction effect was found for both the letter-sounds and rime unit tasks, and the effect sizes of the interaction were large. On the word recognition task, however, no significant interaction effect for time × group was found. Nevertheless, the effect size of the interaction indicated a small effect. There was a significant main effect of time, but no significant main effect of group indicating that both groups developed over time. For the top 50%, a significant time × group interaction effect was found across all three tasks with the GL group showing significantly higher scores and faster development than the control group. Effect sizes of the interaction were large for both letter-sounds and rime units, and medium for word recognition.

An independent samples *t*-test was then conducted to examine group differences at pre- and post-test across the three in-game tasks. For both the bottom 50% and the top 50%, no significant group differences were found at pre-test between the GL and control groups, thus indicating equivalent groups. At post-test, the bottom 50% had significant group differences in favour of the GL group only for the letter-sounds and rime unit tasks. In the top 50%, however, significant group differences at post-test in favour of the GL group were found for all three tasks. Taken together, these findings indicate a stronger effect of GL for children with better pre-existing English literacy skills prior to the start of the intervention. However, significant time × group interaction effects were not found on the oral and paper-based measures, indicating that even in those children who had better pre-existing literacy skills prior to the start of the intervention, the skills learned in GL did not transfer to the oral and paper-based measures.

4 | DISCUSSION

In this study, we aimed to examine whether GL English Rime, a globally recognized computer-assisted reading intervention, could significantly improve the foundational English literacy skills of Grade 1 and 2 ELLs who were attending an English-medium public school in Delhi, India. At the end of a 5-week intervention period, the GL group made significant improvements, particularly on in-game assessments of letter-sound knowledge, rime unit recognition, and word recognition.

Along with significantly higher post-test scores, children who played GL showed faster development across all three in-game measures as compared to children who did not play GL. These results are meaningful in showing that GL was able to quickly and effectively teach letter-sound correspondences, a critical subskill for English word reading, to young ELLs in India. In addition, children displayed that they were able to use this newly acquired knowledge to recognize larger units, such as orthographic rimes, and even words. Oral and paper-based tasks, used to determine if there was a transfer of skills learned in the game to non-game-based tasks of reading and spelling, indicated that there was no transfer. This finding is in line with previous GL studies across various languages which have found positive effects of GL on reading subskills but have failed to see in-game outcomes translating to out-of-game measures, particularly word-level reading (see McTigue et al., 2019). Nevertheless, we believe that these findings are meaningful given that that the children in this study were ELLs and the intervention was carried out over a short duration.

As previously mentioned, GL is adaptive and requires an 80% passing criterion. Consequently, children progress through the game at their own pace. While this is advantageous in allowing for individualized practice, from an efficacy perspective, there are challenges that emerge as a result of differences in players progression. As in previous studies (Worth et al., 2018), in this study there was great variability in children's game progress. Thus, in an attempt to better understand response to GL intervention, we examined if and how game progress related to children's pre-test, post-test, and gain scores. In general, we saw that the children who had higher pre-test scores (i.e., better pre-existing English literacy skills) were also the ones who were progressing further in the game. On the contrary, those children who had more limited English literacy skill were perhaps unable to meet the 80% criterion as quickly and consequently, made less progress given the limited intervention period. Based on these findings, we divided children into new groups based on their pre-test scores which allowed us to examine whether there were differences in the effectiveness of GL for children with different pre-existing English literacy skills as compared to their matched controls. At least for the GL in-game assessment tasks, there were differences in game effectiveness with those children with better pre-existing English literacy skill seemingly benefitting more. These findings are in line with previous GL English Rime studies which have found that existing phoneme awareness skill is predictive of response to GL (Wilson et al., 2021) and those children who do respond to GL seem to make gains (Ahmed et al., 2020).

These findings essentially demonstrate a Matthew effect, a phenomenon commonly discussed in relation to reading (Stanovich, 1986) but also one which has been discussed in relation to educational technology (Trucano, 2013). Children who have some basic level of competencies to engage with reading and technology, will read and engage more, and as a result, reap the greatest benefits. However, given that GL was designed as a practice tool in which it is assumed that children have some level of prior phonological knowledge (Richardson & Lyytinen, 2014), these results are perhaps not all that surprising. When children play GL in their native language, they are able to use their existing phonological awareness skill as a foundation upon which to build and learn from the game. On the contrary, for children like those in this study who lack foundational skills in English, GL alone is perhaps not maximally beneficial as indicated by a lack of effects on the oral and paper-based measures.

4.1 | Game on or game over?

There is no doubt that educational technology has great potential to enhance learning experiences. Computer-assisted games can aid in building motivation, confidence, and excitement for learning. However, from an educational perspective, the larger goal of using such games is to teach skills and not just to teach the game. In other words, it is essential that learners can transfer the skills learned in a game to out-of-game contexts. While a detailed discussion on the mechanisms of transfer is beyond the scope of this paper, we will discuss three broad elements of this study which may have contributed to the findings. The first is regarding the measures that were used, the second is regarding game-based factors, and the third is regarding the method of implementation.

A recent meta-analysis examining the effects of educational apps across 36 intervention studies emphasized that ‘measures matter’ (Kim et al., 2021). Researchers found larger treatment effects in studies which used researcher-developed versus standardized measures and in studies which measure constrained skills (e.g., letter-sound knowledge) versus unconstrained skills (e.g., word reading/vocabulary). Other studies have also shown greater transfer for trained items than untrained items (Görgen et al., 2020; Hintikka et al., 2008). In this study, the oral and paper-based tasks used were standardized measures which were highly unconstrained. In addition, they contained none of the trained items from GL and required children to move beyond simple recognition. In line with previous research, the largest effects were found on the GL tasks in which children were assessed only on those items taught in the game and in a manner most like the game. It is possible that the use of oral and paper-based measures which were more closely aligned to the content taught in GL would have resulted in greater effects.

Although GL supports the development of phonological awareness skills, the phonological awareness tasks used in this study, both phoneme substitution and rhyme oddity, are known to be complex and cognitively demanding (Vandervelden & Siegel, 1995; Wagner & Torgesen, 1987), particularly for children who are ELLs (Pufpaff, 2009). Given that the children in this study had only been learning English for a limited time and there was no classroom emphasis on building phonological awareness skills, it is possible that the phonological awareness tasks were simply too difficult for children to master after a limited intervention period. Many of the oral and paper-based tasks were also distant from what children had practiced in GL. Phoneme replacement was not a task which was explicitly practiced in GL and regarding word reading, in GL, children were practicing word recognition and not oral word production as required for the out-of-game measure. It is also important to remember that out of the three in-game measures, the smallest effects were seen on the word recognition task. Therefore, it is possible that children simply did not build up enough in-game word recognition skill to see a transfer of learning to out-of-game word reading.

Other explanations may lie in the design of the game itself. For one, GL's adaptive features means that at the end of an intervention period children will have only completed as much of the game as they were able to master with 80% accuracy. This also means that there will be variation in how much of the game students will have completed prior to post-testing. In this study, students were able to complete an average of 12 streams (out of 25), with students in the bottom 50% group having completed an average of 7 streams and the students in the top 50% group having completed an average of 17 streams. As mentioned in previous studies, significant effects on decoding were found when children were able to play at least 16 streams (Ahmed et al., 2020). It is difficult to determine if, or how, the results of this study would have changed had more students progressed further or reached game completion, but this is something that warrants further study. Another aspect which requires future exploration is whether the adaptive features of GL are in fact beneficial for these children. Vanbecelaere et al. (2020) conducted an intervention study where they included both an adaptive and non-adaptive version of the game-based intervention and found no additional benefit of adaptation. It would be highly informative to replicate this design using GL.

A second, game-based explanation could lie in the in the content of the game. While GL does aim to support the development of children's phonological awareness skills, its emphasis is limited. Ronimus et al. (2020) acknowledged that the versions of GL used in many previous studies do not explicitly train players' blending and segmenting skills. While GL English Rime does contain word formation levels in which children arrange letter tiles to form a word, this is not a primary focus. For children, such as those in our sample who are in classrooms where phonics is not the norm (see Gupta, 2014), a practice tool alone is not enough.

This brings us to our final, but perhaps most important, explanation of the pattern of results which is the method of implementation. In this study, GL was implemented as a supplement to classroom instruction, but teachers were not asked to make any modifications to their literacy instruction in alignment with GL nor was GL modified to align with existing classroom practices. This was done intentionally to mirror the common reality in India where teachers are provided with technology with little to no training on how to effectively integrate that technology into their teaching practices (Central Square Foundation, 2015). The results of our study reinforce that this type of implementation greatly limits the potential benefits of such interventions.

McTigue et al.'s (2019) meta-analysis on GL found that while a lack of transfer to word reading was prevalent in multiple GL studies across various languages, studies which involved high adult interaction produced an average positive effect ($g = 0.48$; see Saine et al., 2011). Research on other educational technologies have similarly shown that the transfer of learning is enhanced when the learner is provided with various forms of guidance and support (see Tobias & Fletcher, 2007 for review). Such guidance is perhaps even more critical to build certain skills, such as phonological awareness, which are difficult to instruct using technology alone given that they have a large oral component. A previous study examining the effects of a computer-based phonological awareness intervention as compared to teacher-led instruction for young readers found that students in the teacher-led-group significantly outperformed those in the computer-based group on tasks of rhyme discrimination, rhyme production, phoneme isolation, and phoneme segmentation (Mitchell & Fox, 2001). Researchers concluded that while computer-administered instruction allowed children to recognize items presented aurally, it did not give them the opportunity to practice pronunciation, and pronunciation may be required to master the skill. We believe that future GL studies with greater teacher involvement could significantly enhance the effects of the intervention.

4.2 | Limitations

While we believe this study was methodologically strong and makes an important contribution to the limited existing efficacy studies in the Indian context, we recognize that there are limitations. Some of the limitations we have mentioned earlier include a short intervention duration limiting the number of children who could play GL to completion and oral and paper-based measures which were difficult and/or distant from the skills learned in the game.

Regarding the measures used, a limitation of the in-game assessment is the lack of reliability information. Unfortunately, it was not possible to retrieve the reliability information for the version of GL used in this study. However, the reliability of the Finnish version of GL has been examined, and findings have shown that computer-based assessments conducted through GL have high reliability (Hautala et al., 2020). Nevertheless, the GL English Rime in-game assessments require further evaluation. In addition, although we included a wide range of literacy skill assessments, we did not have an oral vocabulary measure which limited our ability to control for children's pre-existing English skills, and thus, we recommend future studies ensure that oral vocabulary is assessed.

Regarding the methods, we did have a limited sample size which results in reduced statistical power. We also would like to acknowledge that the use of a composite score to divide children into the top and bottom 50% groups limits variation and looking at the differences between these groups more in detail is required in future research. Finally, given that India is a highly multicultural and diverse country, it is important to acknowledge that the results of this study are perhaps limited in their generalizability. It is extremely important the efficacy of GL be evaluated in different schools across the country to identify where and with whom GL can be the most beneficial.

4.3 | Practical implications

Overall, the findings from this study shed light on the benefits and constraints of using technology to teach critical skills such as early reading. Policy makers and researchers alike are continuously trying to push the limits of technology. We recognize an urgent need, particularly among the world's most vulnerable populations, to try and quickly improve learning levels before more children fall through the cracks in the system. However, while technology is a means to an end, it is not *the* end.

Research specifically examining the role that technology can play in enhancing reading outcomes is consistently indicating that comprehensive methods in which computer and non-computer based instruction is integrated, and where teachers are provided with professional development, result in greater gains in reading (Cheung & Slavin, 2012; Cheung & Slavin, 2013; Kim et al., 2016; McTigue & Uppstad, 2019). While technology-based interventions allow for individualization, integration is essential in ensuring that there is no misalignment between what is learned in the game and what is instructed in the classroom (Muralidharan et al., 2019).

Educational reform in India clearly goes beyond just the introduction of technological games. There is a clear need to work closely with teachers to help them improve the methods that are being used to teach language and literacy, particularly in English. Technologies, such as GL, can be an effective addition when teachers are adequately trained on when, how, and with whom to use them. In fact, previous research has shown GL intervention to be most effective when used by both teachers and students, rather than just one or the other (Jere-Folotiya et al., 2014). Teachers in India could use similar methods to practice their own understanding of English phonics, which could then better support their instruction. To aid in greater transfer, teachers could integrate GL with classroom literacy instruction to help children make those connections between what they are learning in the game and how they can use that knowledge outside of the game. One way of doing this would be to scaffold learning so that students are not just identifying letter-sounds, rime units, and words in GL but also orally producing them with the teacher.

While classroom instruction into which GL is blended is critical, we understand this relationship between classroom pedagogy and technology should be bidirectional. Therefore, future versions of GL could also be modified to better align with the Indian context. Many children in India come from multilingual backgrounds and it is important to think about how their native language, or other languages they are learning in school, can be utilized in their English literacy learning through GL. Multiple studies in the Indian context have shown children's literacy skills in the first language (L1) to be one of the strongest predictors of their English reading skills (Nakamura & De Hoop, 2014; Reddy & Koda, 2013). Although the examination of the effect of children's L1 skills on their English learning was beyond the scope of this paper, it is highly probable that those children with better English skill, and who seemingly benefitted more from GL, also had better Hindi reading skills. To achieve a more detailed understanding of the skill profiles of the children who can benefit the most from GL in multilingual context, future studies should also include a detailed assessment of L1 literacy skills. Some researchers have suggested aligning English phonics instruction with the stage of phonetic development in children's L1 (Dixon et al., 2011), and others have shown this alignment to be effective, at least with non-technology-based interventions (Nishanimut et al., 2013). Studies replicating these findings using technology-based interventions such as GL could be highly influential.

All in all, the results of this study make an important contribution to research on technology-based English literacy interventions in the context of India and opens the door for topics of future research to enhance the body of evidence around the use of educational technologies to improve literacy in such environments.

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CONFLICT OF INTEREST

The authors declare that the research has been conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

PEER REVIEW

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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REFERENCES

Ahmed, H., Wilson, A. M., Mead, N., Noble, H., Richardson, U., Wolpert, M. A., & Goswami, U. (2020). An evaluation of the efficacy of GraphoGame rime for promoting English phonics knowledge in poor readers. *Frontiers in Psychology*, *5*(132), 1–12. https://doi.org/10.3389/feduc.2020.00132

Annamalai, E. (2004). Medium of power: The question of English education in India. In J. W. Tollefson & A. B. M. Tsui (Eds.), *Medium of instruction policies: Which agenda? Whose agenda* (pp. 177–193). Lawrence Erlbaum Associates.

ASER. (2016). Annual status of education report (rural) 2016. ASER Centre. http://img.asercentre.org/docs/Publications/ASER%20Reports/ASER%202016/aser_2016.pdf

ASER. (2018). Annual status of education report (rural) 2018. ASER Centre. http://img.asercentre.org/docs/ASER%202018/Release%20Material/aserreport2018.pdf

ASER. (2019). Annual status of education report (rural) 2019. ASER Centre. http://img.asercentre.org/docs/ASER%202019/ASER2019%20report%20/aserreport2019earlyyearsfinal.pdf

Bhide, A., Power, A., & Goswami, U. (2013). A rhythmic musical intervention for poor readers: A comparison of efficacy with a letter-based intervention. *Mind, Brain, and Education*, *7*(2), 113–123. https://doi.org/10.1111/mbe.12016

Banerjee, A., Cole, S., Duflo, E., & Linden, L. (2007). Remedying education: Evidence from two randomized experiments in India. *The Quarterly*

Journal of Economics, *122*(3), 1235–1264. https://doi.org/10.1162/qjec.122.3.1235

Byker, E. J. (2014). ICT in India's elementary schools: The visions and realities. *The International Education Journal: Comparative Perspectives*, *13*(2), 27–40.

Byrne, B. (1998). *The foundation of literacy: The child's acquisitions of the alphabetic principle*. Psychology Press.

Byrne, B., & Fielding-Barnsley, R. (1989). Phonemic awareness and letter knowledge in the child's acquisition of the alphabetic principle. *Journal of Educational Psychology*, *81*(3), 313–321. https://doi.org/10.1037/0022-0663.81.3.313

Castles, A., Rastle, K., & Nation, K. (2018). Ending the Reading wars: Reading acquisition from novice to expert. *Psychological Science in the Public Interest*, *19*(1), 5–51. https://doi.org/10.1177/1529100618772271

Central Square Foundation. (2015). The EdTech promise: Catalysing quality school education at scale. http://www.centralsquarefoundation.org/wpcontent/uploads/2015/11/The-EdTech-Promise-Catalysing-Quality-SchoolEducation-at-Scale.pdf

Cherodath, S., & Singh, N. C. (2015). The influence of orthographic depth on reading networks in simultaneous biliterate children. *Brain and Language*, *143*, 42–51. https://doi.org/10.1016/j.bandl.2015.02.001

Cheung, A. C., & Slavin, R. E. (2012). How features of educational technology applications affect student reading outcomes: A meta-analysis. *Educational Research Review*, *7*(3), 198–215. https://doi.org/10.1016/j.edurev.2012.05.002

Cheung, A. C., & Slavin, R. E. (2013). Effects of educational technology applications on reading outcomes for struggling readers: A best-evidence synthesis. *Reading Research Quarterly*, *48*(3), 277–299. https://doi.org/10.1002/rrq.50

Chiappe, P., & Siegel, L. S. (1999). Phonological awareness and reading acquisition in English-and Punjabi-speaking Canadian children. *Journal of Educational Psychology*, *91*(1), 20–28. https://doi.org/10.1037/0022-0663.91.1.20

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Lawrence Earlbaum Associates.

Dixon, P., Schagen, I., & Seedhouse, P. (2011). The impact of an intervention on children's reading and spelling ability in low-income schools in India. *School Effectiveness and School Improvement*, *22*(4), 461–482.

Dutta, U., & Bala, N. (2012). Teaching of English at primary level in government schools. NCERT. http://www.ncert.nic.in/departments/nie/del/publication/pdf/English_Primary_level.pdf

Ehri, L. C. (2003). Systematic phonics instruction: Findings of the National Reading Panel. Paper presented at the invitational seminar by the standards and effectiveness unit, DfES, London.

Ehri, L. C., & Roberts, T. (2006). The roots of learning to read and write: Acquisition of letters and phonemic awareness. In D. K. Dickinson & S. B. Neuman (Eds.), *Handbook of early literacy research* (Vol. 2, pp. 113–131). Guilford Press.

Foulin, J. N. (2005). Why is letter-name knowledge such a good predictor of learning to read? *Reading and Writing*, *18*(2), 129–155. https://doi.org/10.1007/s11145-004-5892-2

Görgen, R., Huemer, S., Schulte-Körne, G., & Moll, K. (2020). Evaluation of a digital game-based reading training for German children with reading disorder. *Computers & Education*, *150*, 103834. https://doi.org/10.1016/j.compedu.2020.103834

Graddol, D. (2010). English next India: The future of English in India. British Council. https://www.britishcouncil.in/sites/default/files/english_next_india_-_david_graddol.pdf

Gupta, R. (2014). Change in teaching practices: Case of phonics instruction in India. *Procedia-Social and Behavioral Sciences*, *116*, 3911–3915. https://doi.org/10.1016/j.sbspro.2014.01.865

Hatcher, P. J., Hulme, C., & Ellis, A. W. (1994). Ameliorating early reading failure by integrating the teaching of reading and phonological skills: The phonological linkage hypothesis. *Child Development*, *65*(1), 41–57. https://doi.org/10.2307/1131364

Hatcher, P. J., Hulme, C., & Snowling, M. J. (2004). Explicit phoneme training combined with phonic reading instruction helps young children at risk of reading failure. *Journal of Child Psychology and Psychiatry*, *45*(2), 338–358. https://doi.org/10.1111/j.1469-7610.2004.00225.x

Hautala, J., Heikkilä, R., Nieminen, L., Rantanen, V., Latvala, J. M., & Richardson, U. (2020). Identification of reading difficulties by a digital game-based assessment technology. *Journal of Educational Computing Research*, *58*(5), 1003–1028. https://doi.org/10.1177/0735633120905309

Hintikka, S., Landerl, K., Aro, M., & Lyytinen, H. (2008). Training reading fluency: Is it important to practice reading aloud and is generalization possible? *Annals of Dyslexia*, *58*, 59–79. https://doi.org/10.1007/s11881-008-0012-7

Huang, F. L., Tortorelli, L. S., & Invernizzi, M. A. (2014). An investigation of factors associated with letter-sound knowledge at kindergarten entry. *Early Childhood Research Quarterly*, *29*(2), 182–192. https://doi.org/10.1016/j.ecresq.2014.02.001

Jere-Folotiya, J., Chansa-Kabali, T., Munachaka, J. C., Sampa, F., Yalukanda, C., Westerholm, J., Richardson, U., Serpell, R., & Lyytinen, H. (2014). The effect of using a mobile literacy game to improve literacy levels of grade one students in Zambian schools. *Educational Technology Research and Development*, *62*(4), 417–436. https://doi.org/10.1007/s11423-014-9342-9

Kim, J., Gilbert, J., Yu, Q., & Gale, C. (2021). Measures matter: A meta-analysis of the effects of educational apps on preschool to grade 3 children's literacy and math skills. *AERA Open*, *7*, 1–19. https://doi.org/10.1177/23328584211004183

Kim, Y. S. G., Boyle, H. N., Zuilkowski, S. S., & Nakamura, P. (2016). Landscape report on early grade literacy. USAID. https://www.globalreadingnetwork.net/sites/default/files/eddata/LandscapeReport_0.pdf

Kyle, F., Kujala, J., Richardson, U., Lyytinen, H., & Goswami, U. (2013). Assessing the effectiveness of two theoretically motivated computer-assisted reading interventions in the United Kingdom: GG rime and GG phoneme. *Reading Research Quarterly*, *48*(1), 61–76. https://doi.org/10.1002/rrq.038

Lesaux, N. K., Rupp, A. A., & Siegel, L. S. (2007). Growth in reading skills of children from diverse linguistic backgrounds: Findings from a 5-year longitudinal study. *Journal of Educational Psychology*, *99*(4), 821–834. https://doi.org/10.1037/0022-0663.99.4.821

Lyytinen, H., Erskine, J., Kujala, J., Ojanen, E., & Richardson, U. (2009). In search of a science-based application: A learning tool for reading acquisition. *Scandinavian Journal of Psychology*, *50*(6), 668–675. https://doi.org/10.1111/j.1467-9450.2009.00791.x

Lyytinen, H., Ojanen, E., Jere-Folotiya, J., Damaris Ngorosho, S., Sampa, F., February, P., Malasi, F., Munachaka, J., Yalukanda, C., Pugh, K., & Serpell, R. (2019). Challenges associated with reading acquisition in sub-Saharan Africa: Promotion of literacy in multilingual contexts. In N. Spaull & J. Comings (Eds.), *Improving early literacy outcomes: Curriculum, teaching, and assessment, IBE on curriculum, learning, and assessment* (Vol. 4, pp. 119–132). Brill Sense.

Lyytinen, H. J., Semrud-Clikeman, M., Li, H., Pugh, K., & Richardson, U. (2021). Supporting acquisition of spelling skills in different orthographies using an empirically validated digital learning environment. *Frontiers in Psychology*, *12*, 675. https://doi.org/10.3389/fpsyg.2021.566220

Major, L., & Francis, G. A. (2020). Technology-supported personalized learning: Rapid evidence review. *EdTechHub*, 1–36. https://doi.org/10.5281/zenodo.3948175

McTigue, E. M., Solheim, O. J., Zimmer, W. K., & Uppstad, P. H. (2019). Critically reviewing GraphoGame across the world: Recommendations and cautions for research and implementation of computer-assisted instruction for word-reading acquisition. *Reading Research Quarterly*, *55*(1), 45–73. https://doi.org/10.1002/rrq.256

McTigue, E. M., & Uppstad, P. H. (2019). Getting serious about serious games: Best practices for computer games in reading classrooms. *The Reading Teacher*, *72*(4), 453–461. https://doi.org/10.1002/trtr.1737

Melby-Lervåg, M., Lyster, S. A. H., & Hulme, C. (2012). Phonological skills and their role in learning to read: A meta-analytic review. *Psychological Bulletin*, *138*(2), 322–352. https://doi.org/10.1037/a0026744

MHRD. (2019). Draft National Education Policy 2019. https://mhrd.gov.in/sites/upload_files/mhrd/files/Draft_NEP_2019_EN_Revised.pdf

Miglani, N., & Burch, P. (2019). Educational technology in India: The field and teacher's sensemaking. *Contemporary Education Dialogue*, *16*(1), 26–53. https://doi.org/10.1177/0973184918803184

Mitchell, M. J., & Fox, B. J. (2001). The effects of computer software for developing phonological awareness in low-progress readers. *Literacy Research and Instruction*, *40*(4), 315–332. https://doi.org/10.1080/19388070109558353

Muralidharan, K., Singh, A., & Ganimian, A. J. (2019). Disrupting education? Experimental evidence on technology-aided instruction in India. *American Economic Review*, *109*(4), 1426–1460. https://doi.org/10.1257/aer.20171112

Muter, V., & Diethelm, K. (2001). The contribution of phonological skills and letter knowledge to early reading development in a multilingual population. *Language Learning*, *51*(2), 187–219. https://doi.org/10.1111/1467-9922.00153

Nagarajan, R. (2015). Number of children studying in English doubles in 5 years. *The Times of India*. https://timesofindia.indiatimes.com/india/Number-of-children-studying-in-English-doubles-in-5-years/articleshow/49131447.cms

Nakamura, P., & De Hoop, T. (2014). Facilitating reading acquisition in multilingual environments in India (FRAME-India) final report. American Institutes for Research. https://www.air.org/sites/default/files/downloads/report/FRAME_Final%20Report_Final.pdf

NCERT (2005). National Curriculum Framework 2005. National Council of Educational Research and Training. https://ncert.nic.in/pdf/nc-framework/nf2005-english.pdf

Nishanimut, S. P., Johnston, R. S., Joshi, R. M., Thomas, P. J., & Padakannaya, P. (2013). Effect of synthetic phonics instruction on literacy skills in an ESL setting. *Learning and Individual Differences*, *27*, 47–53. https://doi.org/10.1016/j.lindif.2013.06.007

O'Brien, B. A., Habib, M., & Onnis, L. (2019). Technology-based tools for English literacy intervention: Examining intervention grain size and individual differences. *Frontiers in Psychology*, *10*, 2625. https://doi.org/10.3389/fpsyg.2019.02625

Patel, P., Torppa, M., Aro, M., Richardson, U., & Lyytinen, H. (2018). GraphoLearn India: The effectiveness of a computer-assisted reading intervention in supporting struggling readers of English. *Frontiers in Psychology*, *9*, 1045. https://doi.org/10.3389/fpsyg.2018.01045

Pritchett, L., & Beatty, A. (2012). The negative consequences of overambitious curricula in developing countries. (Center for Global Development Working Paper No. 293, HKS Working Paper No. RWP12-0350).

Pufpaff, L. A. (2009). A developmental continuum of phonological sensitivity skills. *Psychology in the Schools*, *46*(7), 679–691. https://doi.org/10.1002/pits.20407

Rao, C., Sumathi, T. A., Midha, R., Oberoi, G., Kar, B., Khan, M., Vaidya, K., Midya, V., Raman, N., Gajre, M., & Singh, N. C. (2021). Development and standardization of the DALI-DAB (dyslexia assessment for languages of India—Dyslexia assessment battery). *Annals of Dyslexia*, 1–19. https://doi.org/10.1007/s11881-021-00227-z

Rayner, K., Foorman, B. R., Perfetti, C. A., Pesetsky, D., & Seidenberg, M. S. (2001). How psychological science informs the teaching of reading. *Psychological Science in the Public Interest*, *2*(2), 31–74. https://doi.org/10.1111/1529-1006.00004

Reddy, P. P., & Koda, K. (2013). Orthographic constraints on phonological awareness in biliteracy development. *Writing Systems Research*, *5*(1), 110–130. https://doi.org/10.1080/17586801.2012.748639

Richardson, U., & Lyytinen, H. (2014). The GraphoGame method: The theoretical and methodological background of the technology-enhanced learning environment for learning to read. *Human Technology*, *10*(1), 39–60. https://doi.org/10.17011/ht/urn.201405281859

Ronimus, M., Eklund, K., Westerholm, J., Ketonen, R., & Lyytinen, H. (2020). A mobile game as a support tool for children with severe difficulties in reading and spelling. *Journal of Computer Assisted Learning.*, *36*, 1011–1025. https://doi.org/10.1111/jcal.12456

Saine, N. L., Lerkkanen, M. K., Ahonen, T., Tolvanen, A., & Lyytinen, H. (2011). Computer-assisted remedial reading intervention for school beginners at risk for reading disability. *Child Development*, *82*(3), 1013–1028. https://doi.org/10.1111/j.1467-8624.2011.01580.x

Shenoy, S., Wagner, R. K., & Rao, N. M. (2020). Factors that influence reading acquisition in L2 English for students in Bangalore, India. *Reading and Writing*, *33*, 1809–1838. https://doi.org/10.1007/s11145-020-10047-z

Singh, N.C. (2015). Dyslexia assessment for languages of India (DALI). National Brain Research Centre.

Stanovich, K. E. (1986). Matthew effects in reading: Some consequences of individual differences in the acquisition of literacy. *Reading Research Quarterly*, *21*, 360–407. https://doi.org/10.1598/RRQ.21.4.1

Stuart, M. (1999). Getting ready for reading: Early phoneme awareness and phonics teaching improves reading and spelling in inner-city second language learners. *British Journal of Educational Psychology*, *69*(4), 587–605. https://doi.org/10.1348/000709999157914

The World Bank. (2018). World development report 2018: Learning to realize education's promise. *The World Bank*.

Tobias, S., & Fletcher, J. D. (2007). What research has to say about designing computer games for learning. *Educational Technology*, *47*(5), 20–29. https://www.jstor.org/stable/44429439

Trucano, M. (2005). Knowledge maps: ICT in education. infoDev/World Bank. http://www.infodev.org/en/Publication.8.htm

Trucano, M. (2013). The Matthew effect in educational technology. *The World Bank*. https://blogs.worldbank.org/edutech/matthew-effect-educational-technology

Trucano, M. (2014). Promising uses of technology in education in poor, rural, and isolated communities around the world. *The World Bank*. https://blogs.worldbank.org/edutech/education-technology-poor-rural

Vanbecelaere, S., Van den Berghe, K., Cornillie, F., Sasanguie, D., Reynvoet, B., & Depaepe, F. (2020). The effectiveness of adaptive versus non-adaptive learning with digital educational games. *Journal of Computer Assisted Learning*, *36*(4), 502–513. https://doi.org/10.1111/jcal.12416

Vandervelden, M. C., & Siegel, L. S. (1995). Phonological recoding and phoneme awareness in early literacy: A developmental approach. *Reading Research Quarterly*, *30*, 854–875. https://doi.org/10.2307/748201

Wagner, R. K., & Torgesen, J. K. (1987). The nature of phonological processing and its causal role in the acquisition of reading skills. *Psychological Bulletin*, *101*(2), 192–212. https://doi.org/10.1037/0033-2909.101.2.192

Wilson, A., Ahmed, H., Mead, N., Noble, H., Richardson, U., Wolpert, M. A., & Goswami, U. (2021). Neurocognitive predictors of response to intervention with GraphoGame rime. *Frontiers in Education*, *6*, 125. https://doi.org/10.3389/feduc.2021.639294

Worth, J., Nelson, J., Harland, J., Bernardinelli, D., & Styles, B. (2018). GraphoGame rime: Evaluation report and executive summary. National Foundation for Educational Research. https://www.nfer.ac.uk/graphogame-rime-evaluation-report-and-executive-summary

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III

UNDERSTANDING THE ROLE OF CROSS-LANGUAGE TRANSFER OF PHONOLOGICAL AWARENESS IN EMERGENT HINDI-ENGLISH BILITERACY ACQUISITION

by

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Understanding the role of cross-language transfer of phonological awareness in emergent Hindi–English biliteracy acquisition

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Abstract
This study examined within and cross-language relations, and specifically, the role of phonological awareness (PA) skills in reading among young Hindi-speaking children (L1) who were learning to read English (L2) in Delhi, India. Data was collected from 143 children in Grades 1 and 2 using measures validated for this population. The analyses examined the associations between L1 and L2 PA and decoding, both within and across the two languages. The results showed that PA skills within each language significantly predicted decoding in that language. Furthermore, there was evidence of cross-language transfer with Hindi PA significantly predicting English word reading even after controlling for English PA. English PA also significantly predicted Hindi decoding, however, these effects decreased once Hindi PA was added to the model. These findings emphasize the important role that both L1 and L2 PA plays in reading among emergent Hindi–English bilinguals. The theoretical and practical implications of these findings on literacy instruction in India are discussed.

Keywords Bilingual · Literacy · Hindi–English · Cross-language transfer · Phonological awareness · India

Introduction

Literacy has the power to transform lives, particularly among the world's most vulnerable populations. In countries with great linguistic diversity, however, the path to literacy acquisition is complex. India is home to over 300 million individuals who

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speak two or more of the approximately 462 languages (Simons & Fennig, 2018). The educational policy for language instruction reflects the prevalence of multilingualism, requiring children to learn to read in three languages upon the completion of secondary school, of which two are typically Hindi and English (Joshi et al., 2017). However, there is great variation across the nation in the languages taught, their order, and the time at which they are introduced in school (see Menganathan, 2011). Seen as a language of opportunity, schools are increasingly offering English as a medium of instruction starting in Grade 1. Children in these schools are not only expected to learn to read in the instructional medium (e.g., English) but they are often simultaneously taught one of the Indic languages (e.g., Hindi), requiring the mastery of two distinct writing systems upon school entry (Joshi et al., 2017).

There exists a large and sound body of research on biliteracy acquisition. One of the major findings to emerge from this work has been that phonological skills in the first language (L1) can and do transfer to the second language (L2), as well as vice versa, facilitating reading in both languages (e.g. see Gottardo et al., 2021 for review). However, meta-analyses have revealed variations in these associations based on the languages examined, tasks used, age of the participants, and their instructional/linguistic experiences (Branum-Martin et al., 2012; Melby-Lervåg & Lervåg, 2011), highlighting a need to study these associations in diverse populations and language pairs. Understanding these relations are critical as they may aid in the early identification of children at risk of reading difficulties and can help in the design of effective instruction and remediation.

Studies examining biliteracy acquisition among children in India are greatly limited. Those which have been conducted have largely ignored emergent readers, despite the fact that an increasing number of children are expected to learn to read in two languages upon school entry. Furthermore, existing studies have not examined bidirectional transfer despite evidence that in some languages, phonological processing skills in both L1 and L2 are related to reading in both languages (e.g., LaFrance & Gottardo, 2005). Finally, there are no studies to our knowledge which have specifically examined Hindi–English biliteracy despite these being two widely spoken languages in the country (Office of the Registrar General & Census Commissioner India, 2011). In light of this, the present study aimed to fill some of the gaps in the existing literature base on biliteracy acquisition among children in India by examining the role of L1 and L2 PA on reading in a sample of emergent Hindi–English bilinguals.

The role of phonological awareness in reading

Reading, regardless of language, requires using the sounds of the spoken language to process the written script (e.g., Perfetti, 2003; Perfetti et al., 2005). More specifically, phonological awareness (PA), the ability to recognize, discriminate, blend, and manipulate the sounds in language, has long been identified as a critical skill for reading acquisition (Adams, 1990; Goswami & Bryant, 1990; Wagner & Torgesen, 1987). Prior to formal literacy instruction, PA develops through children's experiences with oral language (e.g., Carroll, 2001; Cooper et al., 2002). As children begin to engage in formal literacy instruction, their phonological sensitivity becomes more refined through instruction and increased exposure to language and print (Anthony & Lonigan, 2004). PA is believed to develop hierarchically, with children in the early stages developing sensitivity to large phonological units (e.g., syllables and rhymes), and over time becoming increasingly more sensitive to smaller units (e.g., phonemes) (Goswami & Bryant, 1990; Treiman & Zukowski, 1991; Ziegler & Goswami, 2005; see Pufpaff, 2009 for review). According to the Psycholinguistic Grain Size Theory, the rate at which these skills develop varies across languages as a result of orthographic differences which affects the *availability* of sounds in the spoken language, the *consistency* in how spoken language maps onto written language, and the *granularity* of the writing system (Goswami, 2010; Ziegler & Goswami, 2005, 2006).

Many of the scripts used across the Indian subcontinent emerged from the Brahmi-derived writing system in which the basic unit of writing is the *akshara* (see Kandhadai & Sproat, 2010 for a detailed description). While languages such as Hindi, Kannada, Oriya, Telugu, etc., have symbol sets that vary in appearance, they all share common psycholinguistic features (Nag, 2011). Each akshara represents either a vowel or a consonant–vowel syllable (e.g. क - /kʌ/, म - /mʌ/). In their primary form, consonants are encoded with an inherent schwa vowel (/ʌ/) which is retained when the vowel appears in the word initial position. Otherwise, the schwa vowel can be replaced with other vowel sounds by placing vowel diacritics before, after, above, or below the consonant or syllable cluster (e.g., कू - /ku:/=क+ऊ; मी - /mi:/=म+ई) (Rao et al., 2021). Thus, although each distinct akshara represents sound at the syllable-level, each syllable consists of distinct phonemic units. As a result, akshara reading requires sensitivity to both syllable and phoneme-level information for decoding (Share & Daniels, 2016; Vaid & Gupta, 2002). Given the availability of distinct phoneme markers, the akshara orthographies are transparent. However, they are highly extensive with a symbol set of over 400 akshara and have great visuo-spatial complexity due to the non-linear arrangement of the symbols (Nag, 2007). Consequently, it has been found that akshara learning continues well into the elementary grades (e.g., Grades 4–5) (Nag, 2011).

The role of phonological awareness in akshara reading

Studies on akshara reading development have been reflective of the dual importance of PA, at both the syllable and phoneme-levels, in decoding (Mishra & Stainthorp, 2007; Nag, 2007; Nag & Snowling, 2012; Nakamura et al., 2018; Reddy & Koda, 2013; Singh & Sumathi, 2019). Singh and Sumathi (2019), examined reading development in 230 children across Grades 1–5 (ages 5–10) who were learning to read Hindi or Marathi. PA was assessed through a rhyme oddity task and a syllable replacement task in each language, and an average score was used for the analysis. PA significantly predicted word reading across grades and for children in Grades 3–5, PA emerged as the strongest unique predictor of both word and pseudoword reading, reflecting the transparent nature of akshara-sound mapping. Unfortunately, due to the use of a composite score, it was not possible to tease apart the various contributions of rhyme versus syllable-level PA.

In a study which examined children across Grades 1–4 it was seen that although both syllable and phoneme-level PA play a role in akshara decoding, syllable-level awareness plays a more dominant role, particularly in the early grades (Nag, 2007). Once children reached Grade 3, and had developed more advanced reading skills, phoneme awareness emerged as a slightly stronger predictor. Nevertheless, syllable awareness has been found to remain significant over time, including among older children (Grades 4–6). The salience of the syllable and its emphasis in reading instruction likely contributes to the stability of syllable-level awareness as a predictor of akshara reading (Nag & Snowling, 2012). A more recent study which examined PA and reading in Kannada and Telugu across children in Grades 1–5 corroborated previous findings (Nakamura et al., 2018). While there were unique contributions of both syllable and phoneme awareness to word reading, children's syllable-level awareness seems to become sharpened over time and eventually subsumes phoneme-level awareness due to the saliency of the syllable in the akshara orthographies.

Bilingual reading and cross-language transfer of phonological awareness skills

PA, viewed as a universally required skill for reading, has received much attention in studies of biliteracy. A major finding to emerge from these studies is that L1 and L2 PA skills are highly correlated, and L1 and L2 PA can predict L1 and L2 reading (Gottardo et al., 2021; Melby-Lervåg & Lervåg, 2011). This finding has since held true across a variety of language pairs such as English–Spanish, English–French, English–Korean, English–Chinese, English–Japanese, English–Kannada, and English–Kiswahili (e.g., Chen et al., 2010; Cisero & Royer, 1995; Comeau et al., 1999; Durgunoğlu et al., 1993; Gottardo et al., 2001; Kim, 2009; Kuo et al., 2016; Reddy & Koda, 2013; Wang et al., 2006; Wawire & Kim, 2018). According to Koda's Transfer Facilitation Model (Koda, 2007, 2008), non-language specific aspects of PA, once developed in the L1, should be available for reading in the L2. As a result, we would expect PA in the two languages to be closely related. However, transfer would be expected to play a larger role when two languages share similar linguistic and orthographic properties which could be shared (Koda, 2008). Therefore, it is likely that different shared skills are transferred depending on the language pair.

Past studies have in fact revealed that there are differences in the facets of PA that transfer as a function of orthographic differences between languages. Bruck and Genesee (1995) found that English-speaking children in Grade 1 who were attending a French-immersion school had more advanced syllable-awareness skills in English than their monolingual peers, due to the saliency of the syllable in French. Chow et al. (2005) examined Chinese kindergarten students who were learning to read English and similarly found that Chinese syllable awareness significantly predicted English reading reflecting the role of the syllable as the basic phonological unit in Chinese. Interestingly, Chen et al. (2010) who examined Chinese children attending an intensive English program as compared to a regular English program found that children in the intensive group showed faster and higher growth on measures of Chinese rime and phonemic awareness, reflective of the phonological features of

English. Thus, although PA is considered to be a language-universal construct, there is clear evidence that the pattern of transfer is reflective of the phonological features of the languages involved (see Branum-Martin et al., 2015), and that this is not only true for transfer from L1 to L2 but also from L2 to L1.

Cross-language transfer of phonological awareness between the akshara languages and English

Few studies have examined cross-language associations among akshara-English bilinguals. Mishra and Stainthorp (2007) conducted one of the first studies and examined 9-year-old (Grade 5) native Oriya speakers. The children attended schools which were either Oriya-medium ($n=48$) or English-medium ($n=51$) and had studied the other language as a subject starting at Grade 2. PA in English was assessed using the Test of Phonological Awareness (Hatcher et al., 1994) and an analogous test developed for Oriya. PA in English and Oriya were found to be highly correlated, however, the cross-language transfer of PA was not symmetrical between children in the two types of schools. For children who attended Oriya-medium school (Oriya is the first literacy language), PA in Oriya predicted decoding in both languages; a finding in line with previous studies of cross-language transfer. In addition, PA in English was found to predict word reading in English indicating that for children in Oriya-medium school, there is evidence of bidirectional transfer.

For children who were attending English-medium school (English is the first literacy language), PA in Oriya predicted pseudoword reading in Oriya and word reading in English and PA in English was found to only predict English decoding. Thus, while there was a role of transfer from the L1 to the L2, there was no bidirectional effect for children in English-medium school. Recognizing the impact of orthographic differences, the authors also examined the role of Oriya syllables versus Oriya phonemes. It was found that for those in Oriya-medium schools, awareness of the syllable made a significant unique contribution to Oriya decoding. Whereas for those in English-medium schools, it was awareness of the phoneme, and not the syllable, that predicted Oriya decoding. Authors concluded that this difference may be an effect of English phonemic awareness facilitating phonemic awareness in Oriya among the English-medium students. Unfortunately, these differential facets of PA were not examined across languages.

In a second study, Reddy and Koda (2013) specifically examined the effects of orthography-specific demands on decoding development among 10–14-year-olds ($n=52$) who had received about four years of literacy instruction in Kannada and one year of literacy instruction in English. PA in both languages was assessed using analogous syllable-deletion and phoneme-deletion tasks. They found that while both syllable and phoneme-level awareness in Kannada contributed to Kannada decoding, only English phoneme-level awareness contributed to English decoding; reflecting the differential roles played by the syllable and phoneme in the two languages. Furthermore, it was seen that syllable and phoneme-level awareness in Kannada significantly contributed to English decoding, but this relationship was mediated by English phoneme awareness.

Purpose of the study

In the present study, we aimed to expand the current understanding of cross-language transfer of PA to include Grade 1 and Grade 2 Hindi speaking children who were attending an English-medium school. Specifically, we examined the strengths of the associations between the following:

1. PA in Hindi (L1) and decoding in Hindi (L1),
2. PA in English (L2) and decoding in English (L2),
3. PA in Hindi (L1) and decoding in English (L2),
4. PA in English (L2) and decoding in Hindi (L1).

We attempt to make three contributions to the gaps in the current research base on cross-language transfer of PA among akshara-English bilinguals. The first is by studying the role of PA in emergent readers. Previous studies conducted in India have all examined children in Grade 4 and above. While it is clear that at least among these older children with sufficiently developed literacy skills we see evidence of transfer, we do not know if the same is true for emergent readers. PA skill is well known to be the most powerful predictor of early reading (e.g., Melby-Lervåg et al., 2012). As students mature, however, PA and its relation to reading becomes less consistent (Scarborough, 2005). An increasing number of children are expected to learn to read in two languages upon school entry when literacy skills in both languages may still be rudimentary, thus it is important to explore patterns of transfer among these populations. Previous studies examining Chinese–English kindergarteners who were receiving literacy instruction in both languages, found a positive effect of L1 PA, specifically syllable awareness, on both L1 and L2 word reading (McBride-Chang et al., 2008). Although these young readers were still developing their PA in their L1, there still seems to be a meaningful role of L1 PA in L2 reading among this population.

The second contribution is the examination of cross-language transfer of PA at multiple grain sizes and bidirectionally. The examination of PA at multiple grain sizes is important as meta-analyses have indicated that composite tasks yield higher cross-language correlations than tasks only assessing PA at the syllable level, implying greater cross-language relations (Branum-Martin et al., 2012). The examination of PA at multiple levels will also allow us to better understand whether different phonological units have differential associations with word reading across the two languages. Although some previous studies in India have used multiple PA tasks (e.g. syllable-level and phoneme-level), these studies have not examined the transfer of these units both from the L1 to the L2 and vice versa. The final contribution is the addition of a new language pair to the research base. Although previous studies have examined akshara-English bilinguals, we believe it is important to replicate this work specifically examining Hindi–English bilinguals given the great amount of linguistic heterogeneity in India.

Method

Participants

The data for this study was collected as part of a larger study (see Patel et al., 2021) which included 143 students in Grades 1 ($n = 70$; $M_{age} = 5.73$, $SD = 0.45$) and 2 ($n = 73$; $M_{age} = 6.68$, $SD = 0.47$) who were attending an English-medium government school in Delhi, India. Prior to the start of the study, parents/guardians were invited to the school and taken through a consent form provided to them in both Hindi and English to ensure they were fully informed of their child's participation. The sample was made up of 43 boys and 27 girls from three Grade 1 classrooms and 31 boys and 42 girls from three Grade 2 classrooms.

The children attended school for approximately six hours per day, five days a week, during which all subject material was presented in English and children learned Hindi for about an hour per day. Hindi literacy instruction focused on the teaching of whole symbol blocks, with children learning the syllables that each akshara in the basic symbol register represents (see for e.g. Nag, 2011). English literacy instruction included some teaching of letter-sound correspondences and word families; however, teachers were heavily reliant on rote reading and copy-writing as is common in many English classrooms across India (see for e.g. Dutta & Bala, 2012).

Information on children's out-of-school language use was collected through a questionnaire provided to the families. Out of 142 respondents, 118 families reported using only Hindi in the home, 19 families reported using both Hindi and English in the home, and 5 families reported using Hindi and/or another Indian language in the home. For children in India, another major source of language input is through private after school tutoring, which a majority of children attend (see Dongre & Tewary, 2014 for a discussion on the impact of private tutoring in India). In our sample, 109 children (76.2%) attended after school tutoring out of which 42 attended Hindi-medium centers, 6 attended English-medium centers, and 60 attended centers where both Hindi and English were used.

Measures

Children's literacy skills were assessed using the Dyslexia Assessment Battery from the Dyslexia Assessment for Languages of India (DALI-DAB) (Singh, 2015). The DALI-DAB is one of the first standardized and validated tools for the assessment of literacy skills in both Hindi and English, designed along similar lines as the Phonological Assessment Battery (PhAB; Frederickson et al., 1997), specifically for use in India (see Rao et al., 2021 for validation details). The DALI contains a separate battery for children in Grades 1–2 and Grades 3–5 to ensure that the tasks are developmentally appropriate, and the tasks were developed keeping in mind the orthographic properties of the respective language. The data used for this study was collected using the semantic fluency, rapid automatized naming (RAN), phonological awareness, and word reading subtests from the Grade 1–2 battery of the DALI in both Hindi and English. An additional word reading task as well as a pseudoword reading task developed for this population, but not a part of the DALI, were also used (Cherodath & Singh, 2015).

Semantic fluency

In the semantic fluency task, participants were given 30 s to name objects in two given categories (i.e., animals and vegetables for Hindi and fruits and vegetables for English). For each language, a sum score of the correctly named items across both categories was used.

Rapid automatized naming (RAN)

RAN was measured using an object naming task from the DALI in which participants were presented with line drawings of five common objects: shoe, flower, house, chair, and key for Hindi and cup, bird, clock, van, and pencil for English, which were randomly arranged in 5 rows of 10 objects each. The participants were asked to name all of the objects in order as quickly as possible and the time taken was measured in seconds.

Phonological awareness (PA)

Hindi syllable replacement In line with the orthographic properties of Hindi in which each akshara represents a syllable unit, PA in Hindi was assessed at the syllable-level using a syllable (akshara) replacement task. The task consisted of two training trials and 10 experimental trials. In each trial, children were orally presented with a word and asked to replace the initial akshara (syllable unit) with a given akshara. (e.g., घर (Gar) with <स>, response = सर (Sar)). A score of one was given for every correctly formed new word. Cronbach's alpha reliability was 0.89.

English phoneme replacement PA in English was assessed as at the phoneme-level through a phoneme replacement task. The task consisted of two training trials and 10 experimental trials. In each trial, children were orally presented with a word and asked to replace the initial phoneme with a given phoneme (e.g., replace /c/ in cot with /g/, response = got). A score of one was given for every correctly reproduced word. Cronbach's alpha reliability was 0.89.

Rhyme oddity PA in both languages was also assessed using a rhyme oddity task consisting of two training trials and 12 experimental trials. In each trial, children were orally presented with three words out of which they were asked to identify the rhyming pair (e.g., Hindi: नाम (naam) – काम (kaam) – नील (neel), English: made—hide—fade). A score of one was given for every correct response. Cronbach's alpha reliability for the Hindi and English rhyme oddity task was 0.80 and 0.83, respectively.

Word reading

Hindi word reading was measured using two separate word lists. The first list was from the Hindi DALI and consisted of 25 words collated from 1st and 2nd grade textbooks, arranged in order of increasing difficulty. The second word reading list consisted of 20 items taken from Grade 1–3 textbooks (Cherodath & Singh, 2015). Children were instructed to read all items and a score of one was given for every correctly read word.

English word reading was also measured using two separate word lists. The first word reading list was taken from the English DALI and consisted of 25 words collated from 1st and 2nd grade textbooks arranged in order of increasing difficulty. The second word reading list consisted of 20 items taken from Grade 1–3 textbooks (Cherodath & Singh, 2015). Children were instructed to read all items and a score of one was given for every correctly read word.

In both Hindi and English, the two word readings lists were found to be highly correlated (Hindi: $r = 0.93$, English: $r = 0.86$), and therefore the averages of the two scores in each language were used for analysis. Cronbach's alpha reliability of the combined word reading list was 0.99 for both Hindi and English.

Pseudoword reading

Pseudoword reading was assessed in both languages using a pseudoword list developed by Cherodath and Singh (2015). The English list consisted of 20 items in which a single letter was replaced in a real word to create a legally pronounceable string in English. Similarly, the Hindi list consisted of 20 items in which a single akshara was replaced to create a legally pronounceable string in Hindi. A score of one was given for every correctly read pseudoword. Cronbach's alpha reliability for the Hindi and English pseudoword reading tasks was 0.94 and 0.91, respectively.

Procedure

Children were brought into a quiet room within the school where they were assessed one-on-one across two sessions, one for Hindi and the other for English, each lasting about 20 min. The assessment sessions were conducted class-by-class, either in Hindi first or English first. Once all six classrooms had been assessed, children were brought back and assessed in the other language, thereby ensuring that children had a sufficient break between the two assessment sessions.

The Hindi tasks were administered by three research assistants who were bilingual English–Hindi speakers. The English tasks were administered by the lead researcher who is a native English speaker and the Hindi–English bilingual research assistants. All of the assessors had a minimum of a bachelor's degree and prior experience working with children. Prior to the start of the study, a training session was held with the assessors on the administration and scoring of the data collection tools to ensure full understanding and consistency.

Data analysis

The data was analyzed using IBM SPSS and R Studio. First, a pairwise *t*-test was conducted to compare children's performance on the Hindi and English measures. Hierarchical linear regression was then employed to examine the unique effects of the various sub-skills in predicting word and pseudoword reading within and across the two languages. In hierarchical regression, predictor variables are added in steps, thereby allowing us to examine the unique effect of each variable(s) over and above the previously entered variable(s). In other words, this method allows us to examine the effect of a variable(s) after controlling for the effects of other variable(s). Effect size was measured using Cohen's f^2 according to which a value of 0.02 is a small effect, a value of 0.15 is a medium effect, and a value of 0.35 is a large effect (Cohen, 1992).

In all the models, children's age, and performance on the semantic fluency and rapid automatized naming (RAN) tasks were entered into the model first, allowing us to control for the variance emerging from differences in age and children's oral language/naming skills. Semantic fluency, while typically used as a measure of executive function, is also affected by vocabulary (Kavé, 2006). RAN, which assesses the ability to rapidly access names from visual symbols, has long been identified as a strong predictor of reading across a variety of languages including English (see for e.g., Compton, 2003) and Kannada (Nag & Snowling, 2012). The phonological awareness measures were then entered into the model in alternating blocks, allowing us to examine the unique contribution of each phonological awareness task over and above the other.

Commonality analysis was conducted to determine the variance contributed by the PA tasks within and across the languages. Commonality analysis allows us to decompose the regression effect into unique and common effects, allowing a more accurate interpretation of the results, particularly when there is multicollinearity among the predictor variables (Kraha et al., 2012; Nimon, 2010). The analysis was conducted using the 'yhat' package (Nimon et al., 2020) in R Studio. We also calculated the squared structure coefficients allowing us to examine the percentage of the regression effect explained by each predictor (Thompson, 2006).

Table 1 Descriptive statistics and paired samples t-test comparison of the Hindi and English measures

	Hindi			English			t (142)
	Min	Max	*M* (*SD*)	Min	Max	*M* (*SD*)	
Semantic fluency	1	21	9.64 (3.60)	0	16	7.26 (3.56)	7.52***
RAN	35	127	66.78 (18.87)	43	161	83.33 (30.25)	−7.64***
Rhyme oddity	0	12	7.57 (3.07)	0	12	5.06 (3.37)	9.81***
H Syllable replacement/E Phoneme replacement	0	10	6.06 (3.63)	0	10	4.26 (3.30)	6.95***
Word reading	0	22.5	17.64 (5.78)	0	22.5	10.83 (6.49)	18.29***
Pseudoword reading	0	20	14.04 (6.22)	0	19	5.47 (5.32)	18.57***

H Hindi, *E* English

***$p < .001$,

Results

Descriptive statistics for the Hindi and English tasks and paired sample *t*-test results comparing children's skills in the two languages are reported in Table 1. Results showed that children performed significantly better on the Hindi tasks, reflecting that Hindi was the more dominant language in this sample. Partial correlations, controlling for the effect of age, are presented in Table 2. The correlations between PA in Hindi and English, decoding in Hindi and English, PA in Hindi and decoding in English, and PA in English and decoding in Hindi were all moderate to high and significant.

Predicting Hindi decoding with Hindi PA

First, hierarchical regression analysis was used to examine the contribution of the Hindi PA tasks to Hindi word and pseudoword reading (see Tables 3, 4 respectively). Age was entered into the model first, followed by Hindi semantic fluency and Hindi RAN as covariates, and finally the Hindi PA tasks were entered in alternating order (Steps 3 and 4) to examine the contribution of each over and above the other.

In predicting Hindi word reading (see Table 3), the total variance explained by the model was 42%, with the Hindi PA tasks explaining 17% of the variance over and above the covariates. Both Hindi rhyme oddity and syllable replacement were found to be uniquely associated with Hindi word reading. Results of the commonality analysis indicated that Hindi rhyme uniquely explained 3% of the variance in Hindi word reading and made 69% of the contribution to the final regression model. Hindi syllable replacement emerged as the strongest unique predictor of Hindi word reading, explaining 6% of the variance and making 67% of the contribution to the final regression model (Table 3, Step 4).

Table 2 Correlations among the Hindi and English variables controlling for age

	1	2	3	4	5	6	7	8	9	10	11	12
Hindi												
1. Semantic Fluency	–											
2. RAN	−.33***	–										
3. Rhyme Oddity	.42***	−.34***	–									
4. Syllable Replacement	.38***	−.29**	.57***	–								
5. Word Reading	.36***	−.37***	.51***	.53***	–							
6. Pseudoword Reading	.39***	−.30**	.54***	.54***	.90***	–						
English												
7. Semantic Fluency	.45***	−.22*	.32***	.37***	.43***	.43***	–					
8. RAN	.35***	.49***	−.39***	−.43***	−.45***	−.50***	−.46***	–				
9. Rhyme Oddity	.39***	−.32***	.54***	.39***	.40***	.48***	.47***	−.42***	–			
10. Phoneme Replacement	.37***	−.31***	.66***	.60***	.52***	.56**	.53***	−.49***	.68***	–		
11. Word Reading	.40***	−.31***	.58***	.55***	.72***	.75***	.54***	−.59***	.53***	.71***	–	
12. Pseudoword Reading	.28**	−.24**	.46***	.44***	.52***	.54***	.47***	−.38***	.48***	.65***	.79***	–

**$p < .01$, ***$p < .001$

Table 3 Hierarchical regression and commonality analysis results predicting Hindi word reading by Hindi phonological awareness

	R^2	ΔR^2	ΔF	Cohen's f^2	β	t	R^2 unique	R^2 common	Total R^2	% of R^2
Step 1	.06	.06	9.59**	–						
Age					.25	3.10**				
Step 2	.25	.19	17.49***	.25						
Age					.08	.99				
Semantic fluency					.29	3.39**				
RAN					−.28	−3.47**				
Step 3	.36	.11	23.36***	.17						
Age					.04	.59				
Semantic fluency					.15	1.77				
RAN					−.19	−2.50*				
Rhyme					.39	4.83***				
Step 4	.42	.06	13.69***	.10						
Age					.09	1.26	.01	.06	.06	12.29
Semantic fluency					.10	1.20	.01	.17	.18	42.86
RAN					−.17	−2.28*	.02	.14	.16	38.10
Rhyme					.24	2.77**	.03	.26	.29	69.05
Syllable					.30	3.70***	.06	.22	.28	66.67
Step 3	.39	.13	30.06***	.23						
Age					.13	1.70				
Semantic fluency					.15	1.82				
RAN					−.20	−2.71**				
Syllable					.40	5.48***				
Step 4	.42	.03	7.69**	.05						
Age					.09	1.26				
Semantic fluency					.10	1.20				
RAN					−.17	−2.28*				

Table 3 (continued)

	R^2	ΔR^2	ΔF	Cohen's f^2	β	t	R^2 unique	R^2 common	Total R^2	% of R^2
Syllable					.30	3.70***				
Rhyme					.24	2.77**				

*$p < .05$, **$p < .01$, ***$p < .001$

Table 4 Hierarchical regression and commonality analysis results predicting Hindi pseudoword reading by Hindi phonological awareness

	R^2	ΔR^2	ΔF	Cohen's f^2	β	t	R^2 unique	R^2 common	Total R^2	% of R^2
Step 1	.03	.03	4.13*	–						
Age					.17	2.03*				
Step 2	.21	.18	15.72***	.23						
Age					− .01	− .12				
Semantic fluency					.35	4.01***				
RAN					− .20	− 2.40*				
Step 3	.35	.15	31.36***	.22						
Age					− .05	− .68				
Semantic fluency					.19	2.23*				
RAN					− .10	− 1.26				
Rhyme					.45	5.60***				
Step 4	.41	.06	13.24***	.10						
Age					− .004	− .06	.000	.03	.03	7.32
Semantic fluency					.14	1.69	.01	.16	.17	41.46
RAN					− .07	− .98	.004	.10	.11	26.83
Rhyme					.31	3.50**	.05	.26	.32	78.05
Syllable					.30	3.64***	.06	.23	.29	70.73
Step 3	.36	.15	32.44***	.23						
Age					.04	.52				
Semantic fluency					.20	2.43*				
RAN					− .12	− 1.52				
Syllable					.43	5.70***				
Step 4	.41	.05	12.28**	.08						
Age					− .004	− .06				
Semantic fluency					.14	1.69				
RAN					− .07	− .98				

Table 4 (continued)

	R^2	ΔR^2	ΔF	Cohen's f^2	β	t	R^2 unique	R^2 common	Total R^2	% of R^2
Syllable					.30	3.64***				
Rhyme					.31	3.50**				

*$p < .05$, **$p < .01$, ***$p < .001$

Table 5 Hierarchical regression and commonality analysis results predicting English word reading by English phonological awareness

	R^2	ΔR^2	ΔF	*Cohen's* f^2	β	t	R^2 unique	R^2 common	Total R^2	% of R^2
Step 1	.07	.07	10.88**							
Age					.27	3.30**				
Step 2	.48	.41	53.96***	.79						
Age					.21	3.39**				
Semantic fluency					.34	4.85***				
RAN					− .41	− 5.92***				
Step 3	.52	.04	12.44**	.08						
Age					.18	3.02**				
Semantic fluency					.25	3.54**				
RAN					− .35	− 5.01***				
Rhyme					.25	3.53**				
Step 4	.62	.10	36.38***	.26						
Age					.18	3.29**	.03	.04	.07	11.29
Semantic fluency					.16	2.38*	.02	.28	.29	46.77
RAN					− .26	− 4.15***	.05	.30	.34	54.84
Rhyme					.004	.05	.000	.30	.30	48.39
Phoneme					.47	6.03***	.10	.40	.50	80.65
Step 3	.62	.14	52.38***	.37						
Age					.18	3.33**				
Semantic fluency					.16	2.42*				
RAN					− .26	− 4.19***				
Phoneme					.48	7.34***				
Step 4	.62	.000	.002	0						
Age					.18	3.29**				
Semantic fluency					.16	2.38*				
RAN					− .26	− 4.15***				

Table 5 (continued)

	R^2	ΔR^2	ΔF	*Cohen's* f^2	β	t	R^2 unique	R^2 common	Total R^2	% of R^2
Phoneme					.47	6.03***				
Rhyme					.004	.05				

*$p < .05$, **$p < .01$, ***$p < .001$

Table 6 Hierarchical regression and commonality analysis results predicting English pseudoword reading by English phonological awareness

	R^2	ΔR^2	ΔF	Cohen's f^2	β	t	R^2 unique	R^2 common	Total R^2	% of R^2
Step 1	.03	.03	4.76*							
Age					.18	2.18*				
Step 2	.28	.25	24.37***	.35						
Age					.14	1.92				
Semantic fluency					.37	4.58***				
RAN					−.21	−2.57*				
Step 3	.34	.06	12.37**	.09						
Age					.11	1.50				
Semantic fluency					.27	3.27**				
RAN					−.13	−1.65				
Rhyme					.29	3.52**				
Step 4	.46	.12	30.83***	.22						
Age					.10	1.57	.01	.02	.03	6.52
Semantic fluency					.17	2.15*	.02	.21	.23	50.00
RAN					−.04	−.55	.001	.15	.15	32.61
Rhyme					.02	.25	.000	.24	.24	52.17
Phoneme					.52	5.55***	.12	.31	.43	93.48
Step 3	.46	.18	46.12***	.33						
Age					.10	1.61				
Semantic fluency					.17	2.21*				
RAN					−.04	−.58				
Phoneme					.53	6.79***				
Step 4	.46	.000	.06	0						
Age					.10	1.57				
Semantic fluency					.17	2.15*				
RAN					−.04	−.55				

Table 6 (continued)

	R^2	ΔR^2	ΔF	Cohen's f^2	β	t	R^2 unique	R^2 common	Total R^2	% of R^2
Phoneme					.52	5.55***				
Rhyme					.02	.25				

*$p < .05$, **$p < .01$, ***$p < .001$

In predicting Hindi pseudoword reading (see Table 4), the total variance explained by the model was 41%, with the PA measures explaining 20% of the variance over and above the covariates. Once again, both Hindi PA tasks were uniquely associated with Hindi pseudoword reading. Hindi rhyme oddity uniquely explained 5% of the variance and accounted for 78% of the total regression effect. Hindi syllable replacement uniquely explained 6% of the variance and accounted for 71% of the total regression effect (Table 4, Step 4).

Predicting English decoding with English PA

Next, we examined the contribution of the English PA tasks to English word and pseudoword reading (see Tables 5, 6 respectively). Once again, age was entered into the model first, followed by English semantic fluency and English RAN as covariates. The English phonological measures were then entered in alternating order to examine the contribution of each, over and above the other (Steps 3 and 4).

In predicting English word reading (see Table 5), the model explained 62% of the variance with the PA tasks explaining 14% of the variance over and above the covariates. When rhyme oddity was the only English PA task entered into the model, it was uniquely associated with English word reading ($\beta = 0.25$, $t = 3.53$, $p < 0.001$). However, once phoneme replacement was entered into the model, rhyme oddity was no longer uniquely associated with English word reading ($\beta = 0.004$, $t = 0.05$, $p = 0.96$). English phoneme replacement ultimately emerged as the strongest unique predictor of English word reading ($\beta = 0.47$, $t = 6.03$, $p < 0.001$). Commonality analysis indicated phoneme replacement uniquely explained 10% of the variance in word reading and accounted for more than 80% of the regression effect, whereas rhyme oddity has a near-zero unique contribution to the model (Table 5, Step 4).

In predicting English pseudoword reading (see Table 6), the model explained 46% of the variance, with the PA tasks explaining 18% of the variance over and above the covariates. Once again, rhyme oddity was uniquely associated with English pseudoword reading when it was the only PA task entered into the model ($\beta = 0.29$, $t = 3.52$, $p < 0.01$). However, once phoneme replacement was entered into the model, the unique contribution of the rhyme oddity task was no longer significant ($\beta = 0.02$, $t = 0.25$, $p = 0.81$). The English phoneme replacement task emerged as the strongest unique predictor of English pseudoword reading ($\beta = 0.52$, $t = 5.55$, $p < 0.001$). Commonality analysis indicated phoneme replacement uniquely explained 12% of the variance in pseudoword reading and accounted for 93% of the regression effect.

Predicting English decoding with Hindi PA

We then examined the contribution of Hindi (L1) PA to English (L2) word (Table 7) and pseudoword (Table 8) reading. Once again, hierarchical regression analysis was conducted with age, English semantic fluency, and English RAN entered first as covariates. In models 1 and 2, the Hindi phonological measures

Table 7 Hierarchical regression and commonality analysis results predicting English word reading by Hindi and English phonological awareness

	R^2	ΔR^2	ΔF	Cohen's f^2	R^2 unique	R^2 common	Total R^2	% of R^2
Model 1								
1. Age	.07	.07	10.88**		.02	.05	.07	11.86
2. E Semantic fluency	.48	.41	53.96***	.79	.05	.24	.29	49.15
E RAN					.05	.29	.34	57.63
3. H Rhyme	.58	.10	32.38***	.24	.05	.32	.37	62.71
4. H Syllable	.59	.02	5.39*	.02	.02	.28	.29	49.15
Model 2								
3. H Syllable	.54	.07	19.90***	.13				
4. H Rhyme	.59	.05	16.64***	.12				
Model 3								
1. Age	.07	.07	10.88**		.02	.05	.07	10.64
2. E Semantic fluency	.48	.41	53.96***	.79	.02	.27	.29	45.31
E RAN	.07	.07	10.88**		.04	.31	.34	53.13
3. E Phoneme	.62	.14	52.38***	.37	.05	.45	.50	78.13
4. H Rhyme	.63	.02	5.77*	.03	.01	.36	.37	57.81
5. H Syllable	.64	.004	1.41	.03	.004	.29	.29	45.31
Model 4								
3. E Phoneme	.62	.14	52.38***	.37				
4. H Syllable	.63	.01	3.14	.03				
5. H Rhyme	.64	.01	3.98*	.03				

E English, *H* Hindi

*$p < .05$, **$p < .01$, ***$p < .001$

were entered to examine the contribution of L1 PA to L2 word reading. Both Hindi rhyme oddity and syllable replacement made a significant unique contribution to English word reading, with Hindi rhyme oddity emerging as the strongest predictor of English word reading in both models ($\beta = 0.29$, $t = 4.08$, $p < 0.001$). Commonality analysis indicated that Hindi rhyme uniquely explained 5% of the variance in English word reading and accounted for 63% of the total regression effect. Hindi syllable replacement uniquely explained 2% of the variance in English word reading and accounted for 49% of the total regression effect.

We then entered the Hindi PA measures after English phoneme awareness, the strongest within-language predictor of English decoding, to examine the contribution of Hindi PA over and above English PA (see Table 7, Models 3 and 4). Hindi rhyme oddity contributed a significant amount of unique variance to English word reading when it was the only Hindi PA task in the model ($\beta = 0.17$, $t = 2.10$, $p < 0.05$). Even after Hindi syllable awareness was added, the contribution of Hindi rhyme remained ($\beta = 0.15$, $t = 2.00$; $p < 0.05$). Hindi rhyme uniquely explained 1% of the variance in English word reading and accounted for 58%

Table 8 Hierarchical regression and commonality analysis results predicting English pseudoword reading by Hindi and English phonological awareness

	R^2	ΔR^2	ΔF	Cohen's f^2	R^2 unique	R^2 common	Total R^2	% of R^2
Model 1								
1. Age	.03	.03	4.76*		.01	.03	.03	7.89
2. E Semantic fluency	.28	.25	24.37***	.35	.06	.16	.23	60.53
E RAN					.005	.15	.15	39.47
3. H Rhyme	.36	.08	16.79***	.13	.04	.20	.24	63.16
4. H Syllable	.38	.01	3.00	.03	.01	.18	.19	50.00
Model 2								
3. H Syllable	.34	.05	11.15**	.09				
4. H Rhyme	.38	.04	8.29**	.06				
Model 3								
1. Age	.03	.03	4.76*		.01	.03	.03	6.38
2. E Semantic fluency	.28	.25	24.37***	.35	.02	.21	.23	48.94
E RAN					.001	.15	.15	31.91
3. E Phoneme	.46	.18	46.17***	.33	.09	.34	.43	91.49
4. H Rhyme	.47	.002	.63	.02	.002	.23	.24	51.06
5. H Syllable	.47	.001	.20	0	.001	.19	.19	40.43
Model 4								
3. E Phoneme	.46	.18	46.17***	.33				
4. H Syllable	.47	.002	.42	.02				
5. H Rhyme	.47	.002	.41	0				

E English, *H* Hindi

*$p < .05$, **$p < .01$, ***$p < .001$

of the total regression effect. Hindi syllable replacement contributed near zero unique variance to English word reading.

In predicting English pseudoword reading (see Table 8), Hindi rhyme oddity contributed significant unique variance in both models 1 and 2 ($\beta = 0.25$, $t = 2.88$, $p < 0.01$). On the contrary Hindi syllable awareness added significant unique variance when entered before Hindi rhyme (see Table 8, Model 2) but not when entered after Hindi rhyme (see Table 8, Model 1). Commonality analysis indicated that Hindi rhyme uniquely explained 4% of the variance in English pseudoword reading and accounted for 63% of the total regression effect. Hindi syllable replacement, while only adding a small amount of unique variance (1%), accounted for 50% of the total regression effect. Neither Hindi rhyme nor Hindi syllable awareness added any significant unique variance to English pseudoword reading when English phoneme awareness was included in the model.

Table 9 Hierarchical regression and commonality analysis results predicting Hindi word reading by Hindi and English phonological awareness

	R^2	ΔR^2	ΔF	Cohen's f^2	R^2 Unique	R^2 Common	Total R^2	% of R^2
Model 1								
1. Age	.06	.06	9.59**		.01	.06	.06	16.22
2. H Semantic fluency	.25	.19	17.49***	.25	.02	.16	.18	48.65
H RAN					.03	.13	.16	43.24
3. E Rhyme	.30	.05	9.16**	.07	.000	.18	.18	48.65
4. E Phoneme	.37	.08	16.62***	.11	.08	.20	.28	75.68
Model 2								
3. E Phoneme	.37	.12	27.00***	.19				
4. E Rhyme	.37	.000	.001	0				
Model 3								
1. Age	.06	.06	9.59**		.01	.06	.06	13.95
2. H Semantic fluency	.25	.19	17.49***	.25	.01	.17	.18	41.86
H RAN					.02	.14	.16	37.21
3. H Rhyme	.36	.11	23.36***	.17	.01	.28	.29	67.44
4. E Phoneme	.40	.04	8.86**	.07	.01	.26	.28	65.12
5. H Syllable	.43	.03	8.08**	.05	.03	.24	.28	65.12
Model 4								
3. H Syllable	.39	.13	30.06***	.23				
4. E Phoneme	.42	.04	8.28**	.05				
5. H Rhyme	.43	.01	2.89	.02				
Model 5								
3. H Rhyme	.36	.11	23.36***	.17				
4. H Syllable	.42	.06	13.69***	.10				
5. E Phoneme	.43	.01	3.46	.02				

E English, *H* Hindi

*$p<.05$, **$p<.01$, ***$p<.001$

Predicting Hindi decoding with English PA

Finally, we examined the contribution of English (L2) PA to Hindi (L1) word (Table 9) and pseudoword (Table 10) reading. Hierarchical regression analysis was conducted, this time with age, Hindi semantic fluency, and Hindi RAN entered as covariates. Next, the English phonological measures were entered in alternating order to examine the contribution of L2 PA to L1 word reading (see Table 9, Models 1 and 2). English rhyme oddity added significant unique variance when entered before English phoneme replacement (Table 9, Model 1) but not when entered after English phoneme replacement (Table 9, Model 2). Commonality analysis indicated a near-zero unique contribution of English rhyme oddity. English phoneme replacement added significant unique variance in both models ($\beta=0.39$, $t=4.08$, $p<0.001$),

Table 10 Hierarchical regression and commonality analysis results predicting Hindi pseudoword reading by Hindi and English phonological awareness

	R^2	ΔR^2	ΔF	Cohen's f^2	R^2 Unique	R^2 Common	Total R^2	% of R^2
Model 1								
1. Age	.03	.03	4.13*		.000	.03	.03	7.89
2. H Semantic fluency	.21	.18	15.72***	.23	.02	.15	.17	44.74
H RAN					.01	.10	.11	28.95
3. E Rhyme	.31	.10	19.46***	.14	.01	.23	.24	63.16
4. E Phoneme	.38	.08	16.99***	.11	.08	.24	.32	84.21
Model 2								
3. E Phoneme	.38	.17	37.23***	.27				
4. E Rhyme	.38	.01	1.37	0				
Model 3								
1. Age	.03	.03	4.13*		.000	.03	.03	6.82
2. H Semantic fluency	.21	.18	15.72***	.23	.01	.16	.17	38.64
H RAN					.003	.10	.11	25.00
3. H Rhyme	.35	.15	31.36***	.22	.02	.30	.32	72.73
4. E Phoneme	.41	.05	12.59***	.10	.03	.30	.32	72.73
5. H Syllable	.44	.03	6.76**	.05	.03	.26	.29	65.91
Model 4								
3. H Syllable	.36	.15	32.44***	.23				
4. E Phoneme	.42	.06	14.03***	.10				
5. H Rhyme	.44	.02	4.50*	.04				
Model 5								
3. H Rhyme	.35	.15	31.36***	.22				
4. H Syllable	.41	.06	13.24***	.10				
5. E Phoneme	.44	.03	6.15	.05				

E English, *H* Hindi

*$p < .05$, **$p < .01$, ***$p < .001$

uniquely explaining 8% of the variance in Hindi reading and accounting for over 75% of the total regression effect.

We then entered English phoneme replacement after the two Hindi PA measures to examine the contribution of English phoneme awareness over and above Hindi PA (see Table 9, Models 3, 4, and 5). English phoneme replacement added a significant amount of unique variance to Hindi word reading when entered after Hindi rhyme (Table 9, Model 3) and when entered after Hindi syllable replacement (Table 9, Model 4), but did not add any significant unique variance when added after both Hindi PA tasks (Table 9, Model 5). Commonality analysis indicated that English PA uniquely explains 1% of the variance in Hindi word reading.

In predicting Hindi pseudoword reading (see Table 10), once again English phoneme awareness contributed significant unique variance in both models 1 and 2 ($\beta = 0.38$, $t = 4.12$, $p < 0.001$). On the contrary, English rhyme oddity only added significant unique variance when added before English phoneme awareness (Table 10, Model 1). Commonality analysis indicated that English phoneme replacement uniquely explained 8% of the variance in Hindi pseudoword reading and accounted for 84% of the regression effect. English rhyme oddity also added a small amount of unique variance to the model.

We then entered English phoneme replacement after the two Hindi PA measures to examine the contribution of English phoneme awareness over and above Hindi PA (see Table 10, Models 3, 4, and 5). English phoneme replacement added a significant amount of unique variance to Hindi pseudoword reading when entered after Hindi rhyme (Table 10, Model 3) and when entered after Hindi syllable replacement (Table 10, Model 4), but did not add any significant unique variance when added after both Hindi PA tasks (Table 10, Model 5). Commonality analysis indicated that English PA uniquely explained 3% of the variance in Hindi pseudoword reading.

Discussion

In this study we aimed to examine cross-language transfer of PA among emergent readers in India. Children in Grades 1 and 2 were simultaneously exposed to Hindi and English literacy instruction in school and were expected to learn to read in two distinct writing systems. Previous studies on cross-language transfer in India which have focused on children in Grade 4 and above have found evidence of L1 phonological transfer to L2 reading (Reddy & Koda, 2013), as well as vice versa (Mishra & Stainthorp, 2007). The results of our study extend these findings to include emergent readers in Grades 1 and 2.

In both Hindi and English, the PA measures of a language were predictive of decoding in that language, highlighting the importance of PA in reading across languages (e.g., Goswami, 2008). Both Hindi PA tasks added a significant amount of unique variance to Hindi word and pseudoword reading, a finding in line with previous studies which have indicated a critical role of PA, particularly large-unit awareness in akshara decoding (Nag, 2007; Nag & Snowling, 2012; Nakamura et al., 2018; Singh & Sumathi, 2019). As previously mentioned, although information is encoded at both the syllable and phoneme-levels in akshara orthographies, it is the syllable that is the salient unit. Early literacy instruction in the akshara languages also tends to focus on syllable-level mappings (Nag, 2007, 2011). As a result, it is perhaps unsurprising that the Hindi syllable replacement task emerged as the strongest predictor of Hindi word reading. Pseudoword reading in Hindi was highly correlated with Hindi word reading, reflective of the orthographic transparency present in akshara languages (Singh & Sumathi, 2019). Consequently, both Hindi phonological tasks were also significant unique predictors of pseudoword reading in Hindi.

When predicting English decoding, English phoneme-level awareness emerged as the single strongest predictor of English decoding. English rhyme oddity, on the other hand, only significantly contributed to English decoding when it was the only PA measure in the model but added no additional variance after controlling for the effect of phonemic awareness. This finding is in line with previous research examining Kannada–English biliteracy among older children (Reddy & Koda, 2013). Ample studies have identified phonemic awareness as one of the most important predictors of reading in alphabetic languages such as English (e.g., Melby-Lervåg et al., 2012), and many studies have shown the benefits of phonemic awareness instruction in helping children read in English (Ehri et al., 2001). The findings of our study show that even for young English language learners with an akshara-based L1, English phoneme awareness is critical for English decoding. Thus, the role of English phoneme awareness is one that cannot, and should not, be ignored in English-medium classrooms in India.

Both Hindi PA measures significantly predicted English decoding when English phoneme awareness was not included in the model, a finding once again in line with previous work examining older students in India (e.g., Reddy & Koda, 2013). When English phoneme awareness was entered into the model, Hindi rhyme oddity continued to add a small but significant amount of unique variance to English word reading. These findings extend previous studies on akshara-English biliteracy and are in line with studies in other language pairs (e.g. Chinese–English; Chow et al., 2005) to show that even in these emergent readers, PA in the L1 transfers to L2 reading. Furthermore, although English decoding is heavily reliant on awareness of the smallest unit, or that of the phoneme, syllable-level awareness is also important given that English is a highly irregular orthography (Ziegler & Goswami, 2005). Syllable awareness has long been known to be one of the earliest available phonological units, emerging even before children begin formal literacy instruction (Treiman & Zukowski, 1991), and is seen as a universal in language processing (Ziegler & Goswami, 2005). Transfer of these non-language specific aspects of PA is also in line with the Transfer Facilitation Model (Koda, 2008).

Although only the Hindi rhyme task was found to add additional variance, it is important to note that, due to the orthographic characteristics of Hindi, rhyme awareness and syllable awareness are essentially testing awareness at the same grain size, that of the syllable (see Cherodath et al., 2017). This is contrary to the English rhyme oddity task which requires onset-rime sensitivity which is considered to be a finer level of sensitivity (Goswami & Bryant, 1990; Treiman & Zukowski, 1991). However, while both Hindi tasks are testing awareness at the level of the syllable, the rhyme task is an identification task whereas the syllable replacement task is a manipulation task. Identification tasks have been recognized as being easier than manipulation tasks (Pufpaff, 2009), a finding that also holds true in this sample where children performed significantly better on the rhyme identification tasks than the manipulation tasks. The contribution of Hindi rhyme, and not syllable replacement, to English word reading may be reflective of differences in task difficulty rather than differences in the type of PA that is being transferred. However, further studies in which the distinction between Hindi syllable and Hindi sub-syllabic units is established are needed to better understand the role of Hindi syllable versus Hindi rhyme awareness and their differential contributions to English decoding.

We also found that phoneme awareness in English (L2) added a significant amount of variance to L1 decoding when L1 PA was not included in the model. However, when L1 PA was added in, there was no longer evidence of transfer from

L2 PA to L1 decoding. However, commonality analysis indicated this may be due to multicollinearity such that once both L2 and L1 PA are in the model, they both lose predictive power. This finding is in line with previous studies which have identified PA as a language general skill (e.g. Cisero & Royer, 1995; Comeau et al., 1999; Kim, 2009). Mishra and Stainthorp (2007) found no evidence of L2 to L1 transfer in children who were going to English-medium school. Interestingly however, evidence of L2 to L1 transfer was found among children who were attending Oriya-medium school. Chung et al. (2013) who examined Chinese–English bilinguals similarly found a lack of L2–L1 transfer. They concluded that a lack of transfer may be due to limited L2 proficiency and that perhaps as children's L2 proficiency increases, there may be stronger bidirectional transfer. Studies which have found evidence of L2–L1 transfer have been in line with this conclusion (e.g. LaFrance & Gottardo, 2005). Future studies are needed to untangle the effects of language proficiency as well as language of instruction in multilingual environments like India.

Limitations

There are some limitations to the present study which should be considered when interpreting the findings. First, although we attempted to control for oral language skill through the semantic fluency measure, children's oral vocabulary was not explicitly assessed. Oral vocabulary is known to play a critical role in children's PA development and word reading skill (e.g., Metsala & Walley, 1998), a finding which also holds true for reading in Hindi (Singh & Sumathi, 2019). In future studies, it is important to assess oral vocabulary in both languages. In addition, using equivalent measures which assess PA at multiple grain sizes (i.e. syllable, onset-rime, and phoneme-levels) in both languages will help provide more specific information on the role of cross-language transfer. Second, the cross-sectional nature of this study prevents us from understanding how associations may change as children develop over time. There is only one longitudinal study, to our knowledge, which has investigated akshara-English biliteracy development in an Indian sample (see Nakamura et al., 2014). However, the youngest group of children in this study were in Grade 3. Thus, future studies are needed in which children's literacy development is followed starting at school entry. Third, this study only reports correlational data. Future studies which employ randomized controlled trials to study the effects of PA and reading instruction can provide valuable insights on how to improve reading development. Finally, it is important to acknowledge the characteristics of the sample when interpreting the generalizability of the results. India is a highly diverse country with an education system that differs greatly from school to school and state to state. Future research should examine cross-language associations in a wide variety of age groups, language pairs, and school types across the country to build a stronger evidence base which is applicable to the Indian population.

Implications

Despite these limitations, this study does provide meaningful insight into the cross-language relationships of young Hindi–English biliterates, a population that has been greatly understudied. While we would encourage researchers to examine this population in greater detail there are important implications, both theoretical and practical, that have emerged from this study. Theoretically, we have shown that L1 and L2 PA transfers to L1 and L2 decoding even among emergent akshara-English bilinguals. This study expands upon previous research on cross-language transfer among akshara-English bilinguals which has focused on children in Grade 4 and above, once children have well developed literacy skills. Through the examination of a younger set of students (Grade 1 and 2) who were simultaneously learning to read in both their L1 and L2 we were able to highlight the importance of PA for decoding both within and across languages. These findings have important practical implications for effective literacy instruction in India.

We see that the role that English phonemic awareness plays in children's English decoding skills, even in this population, is one that cannot be ignored. In line with previous work, it is clear that explicit and systematic instruction that supports the development of English phonemic awareness can successfully aid English reading development (e.g., Dixon et al., 2011). We would encourage teachers and practitioners to better leverage children's L1 literacy skills in helping them develop their L2 literacy skills. As mentioned by Reddy and Koda (2013), this could involve explicitly highlighting the sub-lexical components which are used in both languages. In a study conducted with 10-year-old Kannada-speaking children, researchers found that when an English phonics intervention was modified to include the Kannada symbols which represent the English letters, children performed significantly better on English reading as compared to children who received the English-only intervention (Nishanimut et al., 2013). These findings are promising, although future studies are needed in which such interventions are tested with emergent readers.

We would like to conclude by acknowledging those who have provided sound arguments against the introduction of English prior to the sufficient development of children's literacy skills in their L1 (Nakamura et al., 2019). Studies have shown the role of transfer to be much more significant once children achieve a "threshold level" of literacy in their L1, and thus, researchers are encouraging practitioners and policy makers alike to not introduce English decoding instruction until children have reached the threshold level. Paying heed to these findings, India's New National Education policy has recommended that the medium of instruction until at least Grade 5, but preferably until Grade 8, be the mother tongue or the local language (Government of India Ministry of Education, 2020). However, this remains a recommendation leaving state governments free to decide when and where it will be implemented (Vishnoi, 2020). In India, English-medium instruction starting at school entry is clearly there to stay. Therefore, it is critical that researchers continue to examine literacy development among these populations.

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Authors' contributions Data for this study was collected by Priyanka Patel as part of her doctoral dissertation. Minna Torppa is Priyanka Patel's doctoral supervisor and supported the planning of data collection, data analysis and the writing of the paper. Nandini Chatterjee Singh provided her expertise on Hindi literacy and supported the writing and proofreading of the paper. She also provided all the measures which were used for data collection.

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Availability of data and materials Data and material can be provided by the authors upon request.

Code availability Not applicable.

Declarations

Conflict of interest The authors declare that the research has been conducted in the absence of any relationships that could be construed as a potential conflict of interest.

Ethical approval The study was carried out in accordance with the guidelines provided by the University of Jyväskylä Ethics Committee. A formal ethics approval was not required as per the University of Jyväskylä Ethics Committee guidelines and national regulations, but a statement from the ethics committee can be provided upon request.

Consent to participate Written informed consent was collected from the parents for their child's participation in the study. In addition, permission to conduct the data collection was also taken from the school principal and the respective class teachers.

Consent for publication Not applicable.

References

Adams, M. (1990). *Beginning to read: Thinking and learning about print*. MIT Press.

Anthony, J. L., & Lonigan, C. J. (2004). The nature of phonological awareness: Converging evidence from four studies of preschool and early grade school children. *Journal of Educational Psychology, 96*(1), 43–55. https://doi.org/10.1037/0022-0663.96.1.43

Branum-Martin, L., Tao, S., & Garnaat, S. (2015). Bilingual phonological awareness: Reexamining the evidence for relations within and across languages. *Journal of Educational Psychology, 107*(1), 111–125. https://doi.org/10.1037/a0037149

Branum-Martin, L., Tao, S., Garnaat, S., Bunta, F., & Francis, D. J. (2012). Meta-analysis of bilingual phonological awareness: Language, age, and psycholinguistic grain size. *Journal of Educational Psychology, 104*(4), 932–944. https://doi.org/10.1037/a0027755

Bruck, M., & Genesee, F. (1995). Phonological awareness in young second language learners. *Journal of Child Language, 22*(2), 307–324. https://doi.org/10.1017/S0305000900009806

Carroll, J. M. (2001). *The development of phonological awareness in pre-school children.* [Doctoral dissertation, University of York]. https://etheses.whiterose.ac.uk/9761/1/251812.pdf

Chen, X., Xu, F., Nguyen, T.-K., Hong, G., & Wang, Y. (2010). Effects of cross-language transfer on first-language phonological awareness and literacy skills in Chinese children receiving English instruction. *Journal of Educational Psychology, 102*(3), 712–728. https://doi.org/10.1037/a0018802

Cherodath, S., Rao, C., Midha, R., Sumathi, T. A., & Singh, N. (2017). A role for putamen in phonological processing in children. *Bilingualism: Language and Cognition, 20*(2), 318–326. https://doi.org/10.1017/S1366728916000614

Cherodath, S., & Singh, N. C. (2015). The influence of orthographic depth on reading networks in simultaneous biliterate children. *Brain and Language, 143*, 42–51. https://doi.org/10.1016/j.bandl.2015.02.001

Chow, B.W.-Y., McBride-Chang, C., & Burgess, S. (2005). Phonological processing skills and early reading abilities in Hong Kong Chinese kindergarteners learning to read English as a second language. *Journal of Educational Psychology, 97*(1), 81–87. https://doi.org/10.1037/0022-0663.97.1.81

Chung, K. K., McBride-Chang, C., Cheung, H., & Wong, S. W. (2013). General auditory processing, speech perception and phonological awareness skills in Chinese–English biliteracy. *Journal of Research in Reading, 36*(2), 202–222. https://doi.org/10.1111/j.1467-9817.2011.01500.x

Cisero, C. A., & Royer, J. M. (1995). The development and cross-language transfer of phonological awareness. *Contemporary Educational Psychology, 20*(3), 275–303. https://doi.org/10.1006/ceps.1995.1018

Cohen, J. (1992). A power primer. *Psychological Bulletin, 112*, 155–159. https://doi.org/10.1037/0033-2909.112.1.155

Comeau, L., Cormier, P., Grandmaison, É., & Lacroix, D. (1999). A longitudinal study of phonological processing skills in children learning to read in a second language. *Journal of Educational Psychology, 91*(1), 29. https://doi.org/10.1037/0022-0663.91.1.29

Compton, D. L. (2003). Modeling the relationship between growth in rapid naming speed and growth in decoding skill in first-grade children. *Journal of Educational Psychology, 95*(2), 225–239. https://doi.org/10.1037/0022-0663.95.2.225

Cooper, D. H., Roth, F. P., Speece, D. L., & Schatschneider, C. (2002). The contribution of oral language skills to the development of phonological awareness. *Applied Psycholinguistics, 23*(3), 399–416. https://doi.org/10.1017/S0142716402003053

Dixon, P., Schagen, I., & Seedhouse, P. (2011). The impact of an intervention on children's reading and spelling ability in low-income schools in India. *School Effectiveness and School Improvement, 22*(4), 461–482. https://doi.org/10.1080/09243453.2011.625125

Dongre, A., & Tewary, V. (2014). *Impact of private tutoring on learning levels: Evidence from India.* Accountability Initiative. http://ideasforindia.in/article.aspx?article_id=319#sthash.TffWe6Zs.dpuf/

Durgunoğlu, A. Y., Nagy, W. E., & Hancin-Bhatt, B. J. (1993). Cross-language transfer of phonological awareness. *Journal of Educational Psychology, 85*(3), 453–465. https://doi.org/10.1037/0022-0663.85.3.453

Dutta, U., & Bala, N. (2012). *Teaching of English at primary level in government schools.* NCERT. http://www.ncert.nic.in/departments/nie/del/publication/pdf/English_Primary_level.pdf

Ehri, L. C., Nunes, S. R., Stahl, S. A., & Willows, D. M. (2001). Systematic phonics instruction helps students learn to read: Evidence from the National Reading Panel's meta-analysis. *Review of Educational Research, 71*(3), 393–447. https://doi.org/10.3102/00346543071003393

Frederickson, N., Frith, U., & Reason, R. (1997). *Phonological assessment battery*. NFER-Nelson.

Goswami, U. (2008). The development of reading across languages. *Annals of the New York Academy of Sciences, 1145*, 1–12. https://doi.org/10.1196/annals.1416.018

Goswami, U. (2010). A psycholinguistic grain size view of reading development across languages. In N. Brunswick, S. McDougall, & P. de Mornay Davies (Eds.), *Reading and dyslexia in different orthographies* (pp. 23–42). Psychology Press.

Goswami, U., & Bryant, P. E. (1990). *Phonological skills and learning to read*. Lawrence Erlbaum.

Gottardo, A., Chen, X., & Huo, M. R. Y. (2021). Understanding within-and cross-language relations among language, preliteracy skills, and word reading in bilingual learners: Evidence from the science of reading. *Reading Research Quarterly, 56*, S371–S390. https://doi.org/10.1002/rrq.410

Gottardo, A., Yan, B., Siegel, L. S., & Wade-Woolley, L. (2001). Factors related to English reading performance in children with Chinese as a first language: More evidence of cross-language transfer of phonological processing. *Journal of Educational Psychology, 93*(3), 530–542. https://doi.org/10.1037/0022-0663.93.3.530

Government of India Ministry of Education. (2020). *National Education Policy 2020*. https://www.education.gov.in/sites/upload_files/mhrd/files/NEP_Final_English_0.pdf

Hatcher, P. J., Hulme, C., & Ellis, A. W. (1994). Ameliorating early reading failure by integrating the teaching of reading and phonological skills: The phonological linkage hypothesis. *Child Development, 65*, 41–57. https://doi.org/10.1111/j.1467-8624.1994.tb00733.x

Joshi, R. M., Nakamura, P. R., & Singh, N. C. (2017). Reading research and practice: Indianperspective. *New Dir Child Adolesc Dev, 158*, 43–53. https://doi.org/10.1002/cad.20222

Kandhadai, P., & Sproat, R. (2010). Impact of spatial ordering of graphemes in alphasyllabic scripts on phonemic awareness in Indic languages. *Writing Systems Research, 2*, 105–116. https://doi.org/10.1093/wsr/wsq009

Kavé, G. (2006). The development of naming and word fluency: Evidence from Hebrew-speaking children between ages 8 and 17. *Developmental Neuropsychology, 29*(3), 493–508. https://doi.org/10.1207/s15326942dn2903_7

Kim, Y.-S. (2009). Crosslinguistic influence on phonological awareness for Korean–English bilingual children. *Reading and Writing, 22*(7), 843–861. https://doi.org/10.1007/s11145-008-9132-z

Koda, K. (2007). Cross-linguistic constraints on second-language reading development. In K. Koda (Ed.), *Reading and language learning* (pp. 1–44). Blackwell Publishing.

Koda, K. (2008). Impacts of prior literacy experience on second language learning to read. In K. Koda & A. M. Zehler (Eds.), *Learning to read across languages: Cross-linguistic relationships in first- and second language literacy development* (pp. 68–96). Routledge.

Kraha, A., Turner, H., Nimon, K., Zientek, L., & Henson, R. (2012). Tools to support interpreting multiple regression in the face of multicollinearity. *Frontiers in Psychology, 3*, 44. https://doi.org/10.3389/fpsyg.2012.00044

Kuo, L. J., Uchikoshi, Y., Kim, T. J., & Yang, X. (2016). Bilingualism and phonological wareness: Re-examining theories of cross-language transfer and structural sensitivity. *Contemporary Educational Psychology, 46*, 1–9. https://doi.org/10.1016/j.cedpsych.2016.03.002

LaFrance, A., & Gottardo, A. (2005). A longitudinal study of phonological processing skills and reading in bilingual children. *Applied Psycholinguistics, 26*, 559–578. https://doi.org/10.1017/S0142716405050307

McBride-Chang, C., Tong, X., Shu, H., Wong, A. M. Y., Leung, K. W., & Tardif, T. (2008). Syllable, phoneme, and tone: Psycholinguistic units in early Chinese and English word recognition. *Scientific Studies of Reading, 12*(2), 171–194. https://doi.org/10.1080/10888430801917290

Melby-Lervåg, M., & Lervåg, A. (2011). Cross-linguistic transfer of oral language, decoding, phonological awareness and reading comprehension: A meta-analysis of the correlational evidence. *Journal of Research in Reading, 34*(1), 114–135. https://doi.org/10.1111/j.1467-9817.2010.01477.x

Melby-Lervåg, M., Lyster, S. A. H., & Hulme, C. (2012). Phonological skills and their role in learning to read: A meta-analytic review. *Psychological Bulletin, 138*(2), 322. https://doi.org/10.1037/a0026744

Menganathan, R. (2011). Language policy in education and the role of English in India: From library language to language of empowerment. In H. Coleman (Ed.), *Dreams and realities: Developing countries and the English language*. British Council. https://www.teachingenglish.org.uk/sites/teacheng/files/Z413%20EDB%20Section04_0.pdf

Metsala, J. L., & Walley, A. C. (1998). Spoken vocabulary growth and the segmental restructuring of lexical representations: Precursors to phonemic awareness and early reading ability. In J. L. Metsala & L. C. Ehri (Eds.), *Word recognition in beginning literacy* (pp. 89–120). Lawrence Erlbaum Associates Publishers.

Mishra, R., & Stainthorp, R. (2007). The relationship between phonological awareness and word reading accuracy in Oriya and English: A study of Oriya-speaking fifth-graders. *Journal of Research in Reading, 30*(1), 23–37. https://doi.org/10.1111/j.1467-9817.2006.00326.x

Nag, S. (2007). Early reading in Kannada: The pace of acquisition of orthographic knowledge and phonemic awareness. *Journal of Research in Reading, 30*(1), 7–22. https://doi.org/10.1111/j.1467-9817.2006.00329.x

Nag, S. (2011). The Akshara languages: What do they tell us about children's literacy learning? In R. Mishra & N. Srinivasan (Eds.), *Language-cognition: State of the art* (pp. 291–310). Lincom.

Nag, S., & Snowling, M. J. (2012). Reading in an alphasyllabary: Implications for a language-universal theory of learning to read. *Scientific Studies of Reading, 16*, 404–423. https://doi.org/10.1080/10888438.2011.576352

Nakamura, P. R., de Hoop, T., & Holla, C. (2019). Language and the learning crisis: Evidence of transfer threshold mechanisms in multilingual reading in South India. *The Journal of Development Studies, 55*(11), 2287–2305. https://doi.org/10.1080/00220388.2018.1493192

Nakamura, P. R., Joshi, R. M., & Ji, X. R. (2018). Investigating the asymmetrical roles of syllabic and phonemic awareness in Akshara processing. *Journal of Learning Disabilities, 51*(5), 499–506. https://doi.org/10.1177/0022219417718201

Nakamura, P. R., Koda, K., & Joshi, R. M. (2014). Biliteracy acquisition in Kannada and English: A developmental study. *Writing Systems Research, 6*(1), 132–147. https://doi.org/10.1080/17586801.2013.855620

Nimon, K., Oswald, F., & Roberts, J. K. (2020). *Yhat: Interpreting regression effects. R Package Version 2.0-3*. Available at https://cran.r-project.org/web/packages/yhat/yhat.pdf

Nimon, K. (2010). Regression commonality analysis: Demonstration of an SPSS solution. *Multiple Linear Regression Viewpoints, 36*(1), 10–17.

Nishanimut, S. P., Johnston, R. S., Joshi, R. M., Thomas, P. J., & Padakannaya, P. (2013). Effect of synthetic phonics instruction on literacy skills in an ESL setting. *Learning and Individual Differences, 27*, 47–53. https://doi.org/10.1016/j.lindif.2013.06.007

Office of the Registrar General and Census Commissioner India. (2011). *Census of India: Language*. https://censusindia.gov.in/2011Census/C-16_25062018_NEW.pdf

Patel, P., Torppa, M., Aro, M., Richardson, U., & Lyytinen, H. (2021). Assessing the effectiveness of a game-based phonics intervention for first and second grade English language learners in India: A randomized controlled trial. *Journal of Computer Assisted Learning*, *38*(1), 76–89. https://doi.org/10.1111/jcal.12592.

Perfetti, C. A. (2003). The universal grammar of reading. *Scientific Studies of Reading, 7*(1), 3–24. https://doi.org/10.1207/S1532799XSSR0701_02

Perfetti, C. A., Liu, Y., & Tan, L. H. (2005). The lexical constituency model: Some implications of research on Chinese for general theories of reading. *Psychological Review, 112*(1), 43–59. https://doi.org/10.1037/0033-295X.112.1.43

Pufpaff, L. A. (2009). A developmental continuum of phonological sensitivity skills. *Psychology in the Schools, 46*(7), 679–691. https://doi.org/10.1002/pits.20407

Rao, C., Sumathi, T. A., Midha, R., Oberoi, G., Kar, B., Khan, M., Vaidya, K., Midya, V., Raman, N., Gajre, M., & Singh, N. C. (2021). Development and standardization of the DALI-DAB (Dyslexia Assessment for Languages of India—Dyslexia Assessment Battery). *Annals of Dyslexia*. https://doi.org/10.1007/s11881-021-00227-z

Reddy, P. P., & Koda, K. (2013). Orthographic constraints on phonological awareness in biliteracy development. *Writing Systems Research, 5*(1), 110–130. https://doi.org/10.1080/17586801.2012.748639

Scarborough, H. S. (2005). Developmental relationships between language and reading: Reconciling a beautiful hypothesis with some ugly facts. In H. W. Catts & A. G. Kamhi (Eds.), *The connections between language and reading disabilities* (pp. 3–24). Erlbaum.

Share, D. L., & Daniels, P. T. (2016). Aksharas, alphasyllabaries, abugidas, alphabets and orthographic depth: Reflections on Rimzhim, Katz and Fowler (2014). *Writing Systems Research, 8*(1), 17–31. https://doi.org/10.1080/17586801.2015.1016395

Simons, G. F., & Fennig, C. D. (Eds.). (2018). *Ethnologue: Languages of the world* (21st ed.). SIL International.

Singh, N. C. (2015). *Dyslexia Assessment for Languages of India (DALI)*. National Brain Research Centre.

Singh, N. C., & Sumathi, T. A. (2019). The role of phonological processing and oral language in the acquisition of reading skills in Devanagari. In R. M. Joshi & C. McBride (Eds.), *Handbook of literacy in Akshara orthography* (pp. 261–276). Springer.

Thompson, B. (2006). *Foundations of behavioral statistics: An insight-based approach*. Guilford Press.

Treiman, R., & Zukowski, A. (1991). Levels of phonological awareness. In S. A. Brady & D. P. Shankweiler (Eds.), *Phonological processes in literacy: A tribute to Isabelle Y. Liberman* (pp. 67–83). Lawrence Erlbaum Associates Inc.

Vaid, J., & Gupta, A. (2002). Exploring word recognition in a semi-alphabetic script: The case of Devanagari. *Brain and Language, 81*(1–3), 679–690. https://doi.org/10.1006/brln.2001.2556

Vishnoi, A. (2020, March 30). No switch in instruction medium from English to regional languages with NEP '20: HRD. *The Economic Times*. https://economictimes.indiatimes.com/industry/services/education/no-switch-in-instruction-medium-from-english-to-mother-tongue/regional-languages-with-nep-20/articleshow/77271164.cms?from=mdr

Wagner, R. K., & Torgesen, J. K. (1987). The nature of phonological processing and its causal role in the acquisition of reading skills. *Psychological Bulletin, 101*(2), 192–212. https://doi.org/10.1037/0033-2909.101.2.192

Wang, M., Park, Y., & Lee, K. R. (2006). Korean–English biliteracy acquisition: Cross-language phonological and orthographic transfer. *Journal of Educational Psychology, 98*(1), 148–158. https://doi.org/10.1037/0022-0663.98.1.148

Wawire, B. A., & Kim, Y.-S.G. (2018). Cross-Language transfer of phonological awareness and letter knowledge: Causal evidence and nature of transfer. *Scientific Studies of Reading, 22*(6), 443–461. https://doi.org/10.1080/10888438.2018.1474882

Ziegler, J., & Goswami, U. (2005). Reading acquisition, developmental dyslexia and skilled reading across languages: A psycholinguistic grain size theory. *Psychological Bulletin, 31*(1), 3–29. https://doi.org/10.1037/0033-2909.131.1.3

Ziegler, J. C., & Goswami, U. (2006). Becoming literate in different languages: Similar problems, different solutions. *Developmental Science, 9*(5), 429–436. https://doi.org/10.1111/j.1467-7687.2006.00509.x

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