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Overcoming illiteracy through game-based learning in refugee camps and urban slums

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ABSTRACT

Today 3.7 million refugee children are out of school. The ones forcibly displaced across borders are likely to remain there much of their childhoods and go through an entire school cycle in exile. Without access to quality education, these children have diminished likelihood of breaking free from circular dependency, scarcity, and marginalization. At the same time education sectors globally are adapting to the inevitable increase of digital learning. This study was motivated by the potential availability of digital education, and it argues for non-formal digital game-based learning in refugee and low-resource environments, with a special focus on early literacy.

The participants ($N = 359$) consisted of marginalized, most vulnerable, and out-of-school children aged between 5 and 8. They participated in interventions in Pakistan and Bangladesh for 90 days, two hours a day. The children played digital learning games at their own pace following the learning goals of their national curriculums. The learning outcomes were measured using the EGRA framework.

The study found that the intervention children achieved or surpassed the learning gains of a control group studying through formal education. These results suggest that digital learning games show promise for improving early grade literacy, even in low-resource contexts.

1. Introduction and literature review

1.1. Introduction

Natural disasters, extreme weather, global pandemics, and armed conflicts can jeopardize or interrupt the normalcy of school life. In emergencies the most visible effect is the physical destruction of schools – the second is the unavailability of qualified teachers; both of which are considered crucial in organizing opportunities for conventional teaching and learning [1]. Once interrupted, school life tends to struggle to recover, especially for the displaced. Even when the return to school is eventually achieved, emergencies and displacement inevitably diversify the skill levels of learners [2]. What if the solution for initially bridging the varying gap and ultimately preventing it from ever forming could be the one and the same?

This study explores digital game-based learning by evaluating its suitability for building basic literacy skills for early learners. The study was motivated by the potential benefits of digital game-based learning for early-grade literacy, and it is intended to be generally applicable by focusing on children affected by prolonged crises. In the context of this study a group of children took part in digital game-based learning interventions in the slums of Karachi and in refugee settlements of Dhaka and Cox's Bazar, and young out-of-school children in the mountainous towns of Sultanabad and Karabathang in Northern Pakistan.

Here digital game-based learning was tested in environments where education and especially skills related to basic literacy were not supported by other formal activities. The aim of this study was to investigate the efficiency and suitability of non-formal digital game-based learning interventions in both prolonged emergency settings and low resource contexts. In these circumstances, an international non-profit organization aimed to test if an existing, commercial learning game could have a substantial effect on the achievement of standard curricula educational objectives, even when designed to be used as sole means for literacy education.

In this paper, the claim is approached through a rigorous statistical analysis of test results which are then reflected against the current theories on early grade literacy acquisition, digital game-based learning, and education in emergencies. The research setting provides added significance for the field by focusing on young learners outside of the formal education sector, whose literacy skill development is scarcely

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supported by factors outside the interventions. The paper intents to answer the questions: "How does playing a digital tablet-based game affect early-grade students literacy skills when studying without the help of a teacher?" and "How does playing a digital tabled-based game affect the literacy skills of young out-of-school children?".

1.2. Emergent and early literacy

The development of the ability to read has been widely studied since the emergent literacy paradigm shift that took place over 30 years ago (e.g., [3–7]). Ghoting and Martin-Diaz summarized the ability to read as a combination of alphabetics, comprehension and fluency. In emergent literacy, alphabetics has been found to build on phonological awareness and letter knowledge, comprehension requires vocabulary and narrative skills, and fluency is the combination of alphabetics and comprehension [8].

Disadvantaged socio-cultural environment has been shown to have a negative impact on a child's school performance and especially on the development of skills related to literacy [9]. In short term the effect is apparent in the delayed acquisition of reading and writing skills, which leads to medium- and long-term challenges with studying and accessing information throughout life. Incognito and Pinto [10] found that school can mitigate these negative impacts, with one year of schooling that included emergent literacy measures increasing the students' performance in phonological awareness, notational skills, and textual competence. Even though the access to education is a fundamental human right, disasters, internal displacement, and lack of learning spaces keep millions of children out of school.

1.3. Humanitarian education crisis

A humanitarian emergency can be defined as a disruptive event or series of events that causes a considerable threat to the safety, security, health, or wellbeing of a large group of people, usually over a wide area [11]. Humanitarian emergencies do not occur every time a society is exposed to drought, tornadoes, wildfires, or even armed conflict, but only when the affected society cannot cope with the impact of a disaster using its own resources. Some disasters occur without warning while others develop slowly, their full impact not being felt for years. Likewise recovering from a disaster is usually a gradual process. A study conducted by the Peace Research Institute Oslo in 2017 showed that an average conflict lasts 10 years, and families remain in internally displaced person camps for an average of 17 years [12]. For most children this would mean spending an entire school cycle in exile.

In disasters education can play a critical role in protecting both children and their communities from new risks that stem from the instability following a disaster [13]. However, the focus of humanitarian programming leans heavily towards the physical and mental wellbeing of affected individuals, which leaves the education in emergencies sector with only 3% of humanitarian aid [14]. The failure to prioritize education for individuals suffering from the prolonged effects of emergencies can leave entire generations uneducated, developmentally disadvantaged, and unprepared to contribute to their society's recovery.

The prolonged reduced access to schools caused by disasters is due to a complicated interrelationship between conflict, state fragility, initial low school enrollment and low economic development [15]. This has led to only two thirds of refugee children being enrolled in primary school education [16]. Low- and middle-income counties host almost 90 percent of refugees, and in most cases lack the funds to support their learning [17]. Shortfalls in teaching staff pose major challenges, and for children who do attend school during emergencies the quality of education tends to be very low, which is reflected by class sizes that average at 70 pupils per teacher [18]. Even high-income countries struggle to meet the increased demand; according to an estimate made in 2018 Germany would have required 42,000 new teachers to be able to offer quality education for the children who had arrived as refugees since 2015 [17].

The scale of the indirect impact of conflict on students' access to schools is likely to be greater than the direct and immediate impact that is experienced at a local level, as being denied access to traditional education affects both individuals and their societies. On a personal level interrupted education has a statistically significant negative effect on future personal earnings [19]. On a societal level denied access to education weakens the human capital of a workforce as well as its productivity, leading to decreased growth. The effects of education on the economy have been noted not only by economic growth models, but also by microeconomic studies that highlight the social effects of increased schooling [20]. In this light, it is hard to contest the importance of education in the recovery from crises.

The problems stated here are not limited only to emergency situations. The World Bank estimated that by the age of 10 53% of the children in low and middle-income countries are far behind their expected levels in their reading proficiency [21]. The countries where this study focuses on, Pakistan and Bangladesh, have both long suffered from extensive education crises, as even the children with access to formal education suffer from absent teachers and poor teaching practices ([22], p 225-226, 456-460; [23]). Unlike teachers, however, digital learning solutions have no preferences for the schools in which they work. Therefore, at least in theory, digital learning games have great potential for narrowing the learning gaps and mitigating the lifelong damage caused by education crises.

1.4. Digital game-based learning for early literacy

Digital learning has gradually claimed both physical and theoretical space in learning environments worldwide. In their 2018 report, UNESCO added digitalization of learning as a potential solution for accelerating progress towards ensuring access to primary school for all children. In addition, they recommended stimulating informal learning using information and communication technologies [17]. The report underlined the importance of literacy skills by stating that "Quality education necessitates, at a minimum, that learners develop foundational literacy and numeracy skills as building blocks for further learning, as well as higher-order skills".

In studies focusing on children in general, digital literacy has been shown to create opportunities for them to explore their curiosity, problem-solving and meaning-making skills, all the while enabling them to extend their semiotic repertoires. Multiple studies have proven the link between increased engagement and better learning among young learners when using games focusing on digital literacy (e.g., [24–26]). Digital learning games are also known to support powerful learning strategies, such as situated learning, authentic environments and optimized challenge and support [27,28]. In addition, children playing are often wholly absorbed in the activity of play, enticing them with a sense of joy and interest as they manipulate the objects in the game and explore the learning environments [29].

Autonomous acquisition of early literacy skills through preconfigured devices has not yet been thoroughly explored. Tang [30] showed that preschoolers with basic literacy skills were able to extend their vocabulary autonomously when carefully calibrating the daily size of new vocabulary. Behnamnia et al. [31] found that children benefitted from positive emotions experienced through interaction with digital learning games and that these emotions could be encouraged by external actors such as teachers. They highlighted that the encouragement towards play did not need to come from pedagogical experts and found that continuity of engagement was encouraged by the games themselves.

A few other meaningful studies exist where adult mediators have guided digital game-based learning in classrooms. In India a digital learning game was shown to lead to positive results when developing early literacy skills [32]. Beyond building on the ability to decipher letters and rhymes, one paper found a linkage with digital learning

games and preschoolers' vocabulary learning [33]. Play based learning for early-grade mathematics showed significant learning benefits with urban slums children in India [34] and rural primary schools in Tanzania [35]. In addition to supporting learning, digital game-based assessment has recently been shown to be a reliable and cost-effective way to measure reading fluency and reading accuracy with first to fourth grade students [36].

The scarcity of relevant research becomes apparent when moving the focus from general populations to displaced children and children affected by emergencies. This is likely to be an outcome of the added complexity brought by out-of-school children and children living in slums and refugee camps, who are often hard to reach, represent multiple linguistical and cultural groups and have vastly diverse needs when aiming for becoming literate [1]. In these situations, finding developmentally appropriate practices that would apply to most learners in the learning space is exceedingly challenging [2,37,38]. The complexity arises from not only the innate variability of development levels between individuals, but also from the potentially strong interdependencies between different developmental stages of different abilities and skills. Fortunately, the ability to apply to the wide range of developmental level of the learners is what might set digital game-based learning apart from other technology-enchanted learning methods [28].

2. Methodology

2.1. Study design and participants

The objective of this study is to estimate the impact of digital game-based learning interventions on children's ability to read. More specifically, the study hypothesizes that digital game-based learning can improve early-grade students' literacy skills even when studying without the help of a qualified teacher. The claim is analyzed by measuring the impact of the game-based learning interventions on the overall reading proficiency as well as on the children's performance in the key early-grade reading assessment subtasks measured by the EGRA framework. These tasks include letter name knowledge, initial sound identification, letter sound knowledge, familiar word reading, oral reading fluency, reading comprehension, and listening comprehension.

The longitudal study in this article follows a quasi-experimental design, where the participants, albeit not randomly chosen, represented real-world settings ([39], p. 14). Communities residing in selected locations were informed of the upcoming game-based learning interventions, and children were volunteered to the intervention groups by their parents or caregivers. Majority of the children were already part of empowerment programs run by local non-profit organizations and therefore at least somewhat familiar to the organizers of the interventions. The sessions took place in non-formal community centers. The control subgroups were selected as entire classrooms, with the aim of finding an equal amount of control and intervention group children.

The experiments took place in three diverse geographies where the children belonged to vulnerable communities with low socio-economic status. In Bangladesh, the interventions were organized in Dhaka and Cox's Bazaar for refugee children, and the intervention group comprised of working, out-of-school children and children that had had previous intermittent access to learning through non-formal learning centers. In Pakistan, the interventions were organized in the mountainous villages of Sultanabad and Karabathang and in the slums of Karachi. In Karachi, the children were second or third generation refugees exposed to the prolonged effects of emergencies, currently living in slums and temporary shelters.

A control group was selected for each intervention group so that it would share similar characteristics as the intervention group and therefore represent samples of the same population. The key difference to the intervention group was that the control group children attended traditional classes and therefore had access to the formal learning sector of either Pakistan or Bangladesh. Even though the learning goals were similar for both the intervention and control groups, the control group received most of their education through rote-memorization typical to the region, where children repeated letter names, words, and nursery rhymes after the teacher as a group. Learning materials were scarce, so the instruction was mainly given orally or by writing on a blackboard. For both groups, the classrooms and community centers lacked furniture and the classes were conducted with everyone sitting on the floor.

Across four sites, 359 children who received no formal education for developing their numeracy or literacy skills volunteered to participate in the digital learning program. A control group of 151 students studied the same curriculum under formal learning sector without using digital learning environments. The subgroup size for both control and intervention groups were limited to thirty students per classroom, with some variation in attendance of students, especially with the intervention group. Students who missed either the baseline or end line assessment or who had entries with insufficient identifiers and entries that did not show clear written consent from the participants, or their guardians, were discarded from the thorough analysis described in this article. This translated into the group sizes of intervention ($N = 253$) and control ($N = 106$). The groups are described in Tables 1 and 2.

The facilitator-to-student and teacher-to-student ratio was 1:30 for both experiment and control groups. The students of both groups used dedicated spaces for learning. The intervention children had access to spacious rooms in community centers, while the control group children studied in traditional brick-and-mortar schools and classrooms. Both groups used the same amount of time for learning, where one hour a day was dedicated to learning literacy and another hour was dedicated to basic numeracy. The devices the children used were brought into the learning spaces charged and they did not require internet connection to operate, however, to upload the learning data to servers the tablets needed to be connected through a hot-spot internet device on regular intervals, usually once-a-week.

A baseline assessment was conducted in September 2018 in Pakistan and Bangladesh to determine the literacy and numeracy level of learners in both intervention and control groups prior to the interventions. In November 2018, an end line assessment was conducted for Pakistan and in December 2018 in Bangladesh. Control group, representative of the demographics of students participating in the digital learning interventions, were tested through the same instrument and at the same time as the intervention group.

The intervention group comprised of students engaged in digital learning interventions where the students had extended agency when comparing to a more traditional classroom experience. Although the facilitators explained what the topic of each class was, the students chose which tasks (if any) they chose to play within the gamified world available through the learning game used. The facilitators made sure the children had proper educational applications installed on their tablets and that the children had no technical issues with the devices. The children did not follow so-called traditional learning pedagogies and explored their learning and manipulation skills at their own pace.

Table 1
| Group sizes divided by location.

Group Type	Geographical Location	Female	Male	Total
Control	Pakistan (Urban)	14	21	35
	Pakistan (Rural)	22	17	39
	Bangladesh	18	14	32
Control Total		**54**	**52**	**106**
Intervention	Pakistan (Urban)	28	52	80
	Pakistan (Rural)	60	56	116
	Bangladesh	36	21	57
Intervention Total		**124**	**129**	**253**
Grand Total		**178**	**181**	**359**

Table 2
Group sizes divided by age.

Age	5 to 6	6 to 7	7 to 8	Total
Control	49	10	47	106
Intervention	74	34	145	253
Total	**123**	**44**	**192**	**359**

2.2. Data collection with EGRA and evaluating the ability to read

The significance of the ability to read to education and to adult life in societies that are literacy dependent and literacy-saturated has led to literacy being an extensively covered topic in pedagogical research. Still, evaluating the effectiveness of processes related teaching and learning literacy remains challenging and depends heavily on identifying metrics that can reliably indicate literacy skills acquisition.

In the United States a panel was formed in 1997 to evaluate existing research (already at the time over a 100,000 papers) to find the best ways to teach children to read (RTI, 2009). The work done by the panel included lessons learned from existing procedures and measures for assessing the acquisition of literacy skills, such as Dynamic Indicators of Basic Early Literacy Skills (DIBELS), Test of Phonological Awareness (TOPA) and Comprehensive Test of Phonological Processing (CTOPP). The outcome of the panel was the formulation of the tool used in this study, the Early Grade Reading Assessment (EGRA) (RTI, 2015).

EGRA was created to measure the fundamental skills that readers need to be able to begin to read. Since its inception in 2006, EGRA has been adapted to measure literacy skills in over 100 languages and it has been in use in more than 65 countries [40]. The Research Triangle Institute, or RTI, provides guidance for adapting EGRA to new languages based on the attributes of a specific language and cultural setting. Despite the adaptations of the instrument for different contexts and countries, the subtask-based approach has given researchers a shared language to describe and observe interventions and curriculums on a system-level. For example, when presenting the results on the passage reading subtask, EGRA gives us the means to understand the extent to which the children can handle grade-level text.

EGRA does not capture everything related to literacy development, as it omits institutional analysis such as school readiness and it does not venture into measuring individuals' motivation and socioemotional development. It works best for measuring programmes that use instruction to approach literacy skills development by following predictable patterns through its informed theoretical framework and consistent procedures [40]. The development literacy skills that EGRA excels at measuring fall under three key domains: phonological awareness, print knowledge and orthographic knowledge.

The participants in intervention and control groups were assessed pre-, mid- and post-intervention by using the EGRA toolkit. Assessments based on EGRA were individually administered orally to identify the students' developmental levels for literacy. Oral tests were chosen instead of paper tests to reduce the risk of a floor effect caused by the children's inability to read the questions or to write answers.

Administration of the EGRA took around 20 minutes per learner. The focus of EGRA varies slightly as it is affected by the grade of the student being assessed, but in the scope of this study it always included at least the following competencies:

- Letter Identification
- Phonemic Awareness
- Letter-Sound Knowledge
- Passage Reading and Comprehension

The data collection was conducted using Tangerine, an Android based mobile data collection software. Its primary use is to enable recording students' responses in oral early grade reading and mathematics skills assessments, specifically using the Early Grade Reading Assessment and Early Grade Mathematics Assessment toolkits. To make the assessment of students comparable between classes and subgroups, this article focuses only on the subtasks of EGRA that were administered to all groups. The analysis therefore focused on letter sounds, letter names, the student's ability to read selected words appropriate to their developmental levels and their ability to read two separate nursery rhymes.

The letter names test measured how many letters a student could read per minute. Similarly, in the letter sounds test the students were asked to name as many lowercase letters as they could within a minute. In the words read test, which is also known as correct isolated words read per minute test, the student was asked to read a list of one or two syllable words drawn from a corpus of familiar and frequent words presented in a random order. The Rhyme 1 was the nursery rhyme called "Itsy Bitsy Spider" and Rhyme 2 was "ABC song". The students were asked to read or sing out each of the rhymes, with a time limit of 80 seconds per rhyme.

The assessments were conducted by a group of trained local enumerators. The learning outcomes were evaluated using the standardized metrics of the EGRA framework. The data collection followed the difference in differences nonequivalent control-group-design, where students were measured before, in the middle of and after the learning interventions. The midline assessments supported the interventions by identifying any outliers caused by unexpected factors such as technical difficulties, however the analysis in this paper focuses only on the baseline and end line assessments.

2.3. The games by Footsteps2Brilliance

In the early-literacy learning interventions studied in this research, the children experimented with digital game-based learning through playing either the game "Footsteps2Brilliance" or "Clever Kids University Pre-K". Both of the games are from the same software developer, and they are supposed to support struggling readers literacy development through environmental print, literacy experiences, and explicit instruction. The games have internal categorizations for classrooms, with Clever Kids University supporting learners from ages 2 to 5, and Footsteps2Brilliance having levels ranging from preschool to third grade. In this intervention the children aged 5 played the Clever Kids University Pre-K, and the children aged 6 to 8 played Footsteps2Brilliance.

The games approach literacy domain through tasks focusing on cognitive development, vocabulary, phonics, phonological awareness, visual-motor integration in hand writing, and literal, inferential, lexical and applied comprehension. The main activity in both the games focuses on listening and reading themed short stories. In these stories each virtual page has an age-appropriate number of words, and the sentences are supported by simple, colorful, and interactive graphics. When reading the books, the learner can replay words, sentences, and pages where necessary. The retention of the vocabulary is trained through simple follow-up mini games that allow the learner to draw and organize letters, reconstruct words, identify, and produce initial sounds in words, trace letters and identify words that rhyme. The games use basic gamification elements such as point counters and achievements. Reflection is encouraged by offering the players the possibility to retell the stories they have already explored by using words, illustrations, and clipart.

The progression through the levels in Footsteps2Brilliance closely resembles the curriculums used in the control groups' formal education, with gradual focus on the learner's cognitive development, language, phonics, phonological awareness, literature, and writing. The games use the three-tier vocabulary system identified by Beck, McKeown, and Kucan [41, p 1-18]. The first tier consists of words that children usually learn by listening to adults and peers, and the words in this tier generally do not require instruction. The second tier consists of words that can be considered to form the "richness" of a language, and the third tier is formed by words from specific domains that require the domain to be studied. The games target the first and second-tier vocabularies. The

tiers are introduced progressively, and learners with existing knowledge are able to quickly pass-through levels and reach exercises that challenge their abilities, encouraging flow-states in learning.

2.4. Ethics

This article aimed to maintain high ethical standards with commitment from both the data collectors and researchers. This was approached through ensuring that the studied subjects gave their consent for participating in the research and approved the related data collection and analysis. As the subjects were children the consent was acquired from their legal guardians. Both the guardians and the participating children were explained that they could opt-out of the study at any time without any repercussions. Besides obtaining informed consent, the wellbeing of the subjects was ensured by training the facilitators to consider basic needs of the children and to observe any signs of psychological and physical distress or discomfort. While no psychological distress related to the interventions was reported, the children occasionally suffered slight discomfort from extended use of headphones, which was countered by giving the children short breaks in wearing them.

In addition, great care was taken to ensure complete anonymization of subjects in accordance with the EU General Data Protection Regulation (GDPR) [42]. All parts of the collected data that could make the participants identifiable directly or indirectly were removed. None of the published outcomes contain individual information, but rather only statistics that indicate correlations between identified variables. In addition to removing the student names, addresses, family details, and classroom information, the unique case identifiers that link the result data between base- and end line were obfuscated. The original data was securely erased after the obfuscation.

2.5. Interventions and procedures

In the interventions a digital learning game focusing on reading was provided to each child through tablet computers. Even though the children did study without a teacher, each group was supported by a facilitator. The facilitator's role was to ensure the children's wellbeing and potentially provide necessary guidance to students in case they faced any issues to run or access the learning content. The tablets were intended to offer the students the learning materials in an engaging, sequenced, and interactive, gamified format.

The intervention length was limited to three months. The length was constrained due to the experimental nature of the interventions and the high emphasis on the principle of do-no-harm. As the implementing parties could not without a reasonable doubt be promised an efficient alternative to formal education the focus remained on a playful approach that in many ways resembled a digital recess rather than an actual formal class.

In all sessions, the agency was to be with the child, who progressed according to their pace and at their own level. The facilitators and coordinators who all came from local communities were trained by the non-governmental organization staff and were offered continuous online support. To ensure consistency in the setup and management of the interventions in different locations the facilitators were provided with a guidebook, which assisted them in managing their day-to-day activities during the interventions, such as cleaning and sterilizing the tablets, maintaining their charge levels and supporting the children in logging into their learning sessions.

The learning game included an individual log-in for each child. The children used sets of generic symbols as passwords and most children were able to join their sessions without external support after a week of practice. The game collected data on each child's progress and grouped the children in classrooms. The data included a multitude of formative assessments the game concluded in the background, and it affected the way content was provided to the learners. An online portal was available to the organizers of the interventions with aggregated data on each learner. For interventions focusing on blended learning a skilled pedagogic specialist could benefit from this data by gaining insights on the strengths and weaknesses of each learner, however in the case of this paper the data was not used.

3. Analysis and results

This paper intents to answer two questions: "How does playing a digital tablet-based game affect early-grade students literacy skills when studying without the help of a teacher?" and "How does playing a digital tabled-based game affect the literacy skills of young out-of-school children?". To answer these questions two groups of children were assessed at the beginning and at the end of the interventions using EGRA framework. The statistical analysis below identifies differences between groups based on each sub-task of the EGRA framework and rigorous models and processes analyzed the significance of these differences. The EGRA scores used here represent the percentage of correct answers. The approach was chosen due to its relative simplicity and its established evidence base that strongly implied EGRA to be an effective tool for measuring reading skills in the developing world.

As the sample could not be called representative due to the non-randomized approach, the data analysis focused on effect size to be able to identify the magnitude of the difference between intervention and control groups to understand the effect the interventions had on the student's ability to read. For this purpose, EGRA is considered to provide valid and reliable information on child's ability read, based on its informed theoretical framework and clear guidance that enable consistent use of procedures [40].

The core focus of the statistical analysis of this article is on the comparison between the baseline and end line assessments of the control and intervention groups. Paired samples t-test was used to compare the means of these two groups to determine if there was statistical evidence that the associated population means were significantly different. Statistical differences between the base- and the end-line EGRA scores were examined with repeated measures ANOVA (GLM). The mean sum percentiles were calculated from the multi-item measures and used as variables in the analysis. Repeated measures ANOVA tested the "group" and "time*group" interaction examining the effect of the intervention with regards to mean change over time across groups in the variables. Effect sizes were calculated and analyzed for each EGRA subtask to quantify the magnitude of the difference between the groups to understand the effect the interventions had on the student's ability to read.

Shapiro-Wilk test was used to determine whether the distributions were normal, and with all the larger samples histograms and Q-Q plots were used for supporting the normality assessment. The descriptive statistics for all the tasks for both pre- and post-intervention tests are shown in Table 3.

Fig. 1 shows an example of the high number of zero-scores which turned out to be common in all the baseline tests, which indicated non-normality. Skewness and Kurtosis were measured for all the tests, and the tests related to letter sounds, nursery rhyme 1 and words read did not fulfill the kurtosis requirement due to the zero-score flooring effect. Analysis of variance for repeated measures was used to compare the effects of time (baseline, end line), group (control, intervention) and time multiplied by group (group differences with the change in time) (Table 4, Picture 1, Picture 2).

To counter the high level of zero scores the analysis was repeated as a non-zero analysis, where all students scoring zero points at baseline were omitted from the tests. This normalized the scores and led to all tests fulfilling skewness and kurtosis requirements, however as a consequence this also led to the intervention having significant effect sizes only in the rhyme 1 (effect size 0.155, $p < 0.001$) and rhyme 2 (effect size 0.175, $p < 0.001$). The final analysis was done using the zero scores, with the acknowledgement that the usage of such true scores led to attenuated variance estimates and therefore potentially biased t-test

Table 3
Descriptive Statistics ($N = 359$).

	Letter Name Base (%)	Letter Name End (%)	Letter Sound Base (%)	Letter Sound End (%)	Rhyme 1 Base (%)	Rhyme 1 End (%)	Rhyme 2 Base (%)	Rhyme 2 End (%)	Words Read Base (%)	Words Read End (%)
Mean	34.4	50.4	11.3	21.3	13.0	45.8	35.6	75.3	14.2	36.5
Median	22.5	52.5	0.0	10.0	0.0	45.0	31.3	93.8	6.0	30.0
σ	35.2	36.2	22.2	26.2	29.2	43.1	35.9	33.2	21.7	31.8
Variance	1236.9	1309.0	493.3	687.6	850.3	1858.7	1290.4	1099.4	472.5	1008.2
Skewness	0.6	0.0	2.4	1.3	2.2	0.1	0.4	-1.2	2.0	0.6
Skew. $\Sigma\bar{x}$	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Kurtosis	-1.2	-1.5	4.9	1.0	3.3	-1.8	-1.3	0.1	3.5	-0.8
Kurtosis $\sigma\bar{x}$	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3

Table 4
| Internal Reliability for the selected measures (Cronbach's Alpha).

Measure	Internal Reliability
Letter Name	0.78
Letter Sound	0.45
Rhyme 1	0.51
Rhyme 2	0.24
Words Read	0.58

and ANOVA statistics [43]. The flooring also had a diminishing effect on the Cronbach's alpha (Table 2).

3.1. Baseline and end line group comparisons

(A new intro still needed here) The averages scores and the standard deviations are shown in Table 5.

Table 6 shows the results of the multivariate tests for time and time multiplied by group type. The Pillai's trace describes how much the variable contributed to the model, with positive values of the statistic indicating a larger effect. This is followed by the F-values for the repeated measures ANOVA and their significance. The effect sizes are represented by the values of eta square.

The effects are measured through repeated measures analysis of variance. The effect of time represents the variance between base- and end line scores, and the group multiplied by time represents the combined effect of time and belonging to either control or intervention group.

Paired samples t-test was used to examine the group differences between baseline and end line measurements, which are shown in Table 7.

As can be seen from Table 6 the Time*Group effect was significant for letter sounds and both rhymes. The rather large effect indicates that the intervention had a positive effect on the children's ability to read the short rhymes in the given time. In addition, as seen in Table 7, the intervention showed a significant and large increase in the mean scores of the intervention group in all the subtasks, with the rhymes being once again the exercise types where the intervention had the largest effect.

4. Discussion

Child's early literacy develops gradually and is strongly influenced by external guidance [10]. Unlike verbal skills, literacy requires meaningful samples, text, to form connections between letters, rhymes, and words in the learner's mind [44]. Most often these connections are created in classrooms with the support of a kindergarten, pre-school, or primary school teachers and, if lucky, books that match the child's level of vocabulary and fluency. An emergency has the power to break this process and incapacitate the precious trinity by preventing the learner from accessing the learning environment, learning materials, or pedagogically skilled support [15]. This is where digital learning games might come into play.

The participants of this study were between the ages of five to eight

Picture 1. Learning space is Karabathang, Pakistan.

Picture 2. Intervention group learning space in Dhaka, Bangladesh.

years, and they studied to learn to read. The members of the intervention group played a digital learning game for approximately two hours a day for 90 days. During the first hour the children were encouraged to focus on the literacy aspects of the game, and during the second hour the children were asked to switch to activities in the game focusing on numeracy. At the same time, the control group children participated in formal learning, using equal amount of time to achieve the same learning objectives.

An EGRA assessment identified significant differences at baseline between control and intervention groups. The differences were due to the intervention children consisting of out-of-school children, whereas the control group children had had from one to three years of exposure to formal learning environments. Both groups showed learning gains between base- and end line measurements, however the intervention group progressed more in some of the key sub-tasks. Each group was tested verbally, and they experienced equal amounts of tests, so it is unlikely that the testing itself would have had a significant effect on the children's learning outcomes.

The participants of the intervention group made significant progress and the effect size was promising in letter sounds and very high in memorizing both nursery rhymes. The effect size was highest with the second rhyme ABC Song and almost equally high with the first rhyme Itsy Bitsy Spider. The group differences were significant in all the tests except with Letter Names and Words Read. The reliability of the results related to letter sounds, rhyme one and words read was reduced by the flooring effect related to the high zero-score count, which was visible in the high kurtosis values and low Cronbach's alpha. The zero scores were especially high in the baseline tests of the intervention children, which supports the assumption that most of the intervention children had had little to no exposure to formal education prior to the intervention.

The positive learning outcomes related to the tests measuring letter sounds indicates that the students playing a learning game improved their sensitivity related to phonemes and therefore achieved learning outcomes that previously were assumed only to develop through guided, in-person literacy instruction. Letter-sound knowledge is strongly affected by whether the sound of the letter occurs in the letter name [45], which would make it very interesting to compare the results between letter sound and letter name tests letter by letter in a more detailed study.

Strong phonemic awareness is one of the best predictors of later reading success [46]. Phonological awareness has previously been clearly attributed to develop under formal education settings, as it can easily be improved through repetitive exercises such as linguistic games and activities that rouse the sense of rhythm and the ability to differentiate between specific sounds [10]. The games used in this intervention included multiple activities focusing on similar repetitive exercises, effectively substituting the formal learning environment with a digital informal one.

Both intervention and control groups showed improved learning outcomes in letter names, but the probability value showed that based on this study alone the development could not be attributed to the interventions. The scores in the test measuring the children's awareness of letter names improved by approximately 15 percentage points with both control and intervention groups and belonging to one group or another had no significant effect on the improvement of one's score.

Table 5
Descriptive statistics of selected EGRA tasks for baseline and end line.

Measure	Assessment	Intervention (SD)	Control (SD)
Letter names	Baseline	31.3% (35.9)	41.8% (32.3)
	End line	48.1% (37.6)	55.8% (32.0)
Letter Sounds	Baseline	11.8% (23.3)	10.1% (19.4)
	End line	25.8% (28.3)	10.5% (16.1)
Rhyme 1	Baseline	17.0% (32.8)	3.4% (13.8)
	End line	62.7% (39.0)	5.5% (19.1)
Rhyme 2	Baseline	36.5% (37.8)	33.3% (31.0)
	End line	91.4% (17.6)	36.8% (29.9)
Words Read	Baseline	14.6% (22.3)	13.1% (20.3)
	End line	35.6% (31.5)	38.6% (32.4)

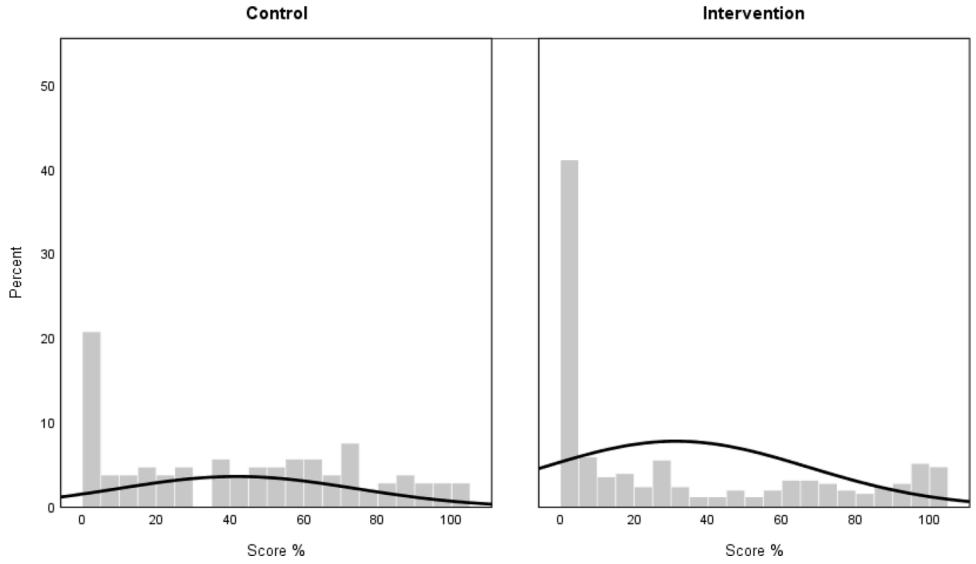

Fig. 1. An example of the high number of zero scores in the letter name baseline test.

Table 6
| Group effects based on repeated measures ANOVA of selected EGRA tasks.

Multivariate test	Time					Time * Group				
Measure	Pillai's trace	df	F	p	η^2	Pillai's trace	df	F	p	η^2
Letter names	0.18	357	76.44	<0.01	0.18	0.02	357	0.62	0.431	0.02
Letter sounds	0.05	357	19.49	<0.01	0.05	0.05	357	17.34	<0.01	0.05
Rhyme 1	0.25	357	121.73	<0.01	0.25	0.22	357	101.56	<0.01	0.22
Rhyme 2	0.32	357	165	<0.01	0.32	0.26	357	127.37	<0.01	0.26
Words Read	0.34	357	184.6	<0.01	0.34	0.05	357	1.69	0.195	0.005

Table 7
| Paired samples t-test for base and end line scores (percentage).

Group Type	Subtask	t (df)	95% CI	Effect size (Cohen's D)
Control	Letter names***	4.9 (105)	[8.3, 19.7]	0.48
	Letter sounds	0.2 (105)	[-4, 4.8]	0.18
	Rhyme 1	0.9 (105)	[-2.5, 6.6]	0.87
	Rhyme 2	1.4 (105)	[-1.7, 8.7]	0.12
	Words read***	8.6 (105)	[19.6, 31.3]	0.84
Intervention	Letter names***	8.7 (252)	[13, 20.6]	0.54
	Letter sounds***	7.4 (252)	[10.3, 17.8]	0.46
	Rhyme 1***	17.4 (252)	[40.5, 50.8]	1.09
	Rhyme 2***	20.1 (252)	[49.5, 60.2]	1.26
	Word read***	11.5 (252)	[17.4, 24.6]	0.72

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

Similarly, children in both groups saw significant improvement in the subtasks measuring how many words they could read in a set time. Like with letter names, the intervention group did not study literacy outside of the intervention, however without having an out-of-school control group not participating in intervention it is impossible to say whether the change happened due to the intervention, school, or due to other activities not observed under this research.

The lack of improvement related to learning letter names could have been affected by the way the interventions were organized, which included the children having a high level of agency in relation to their own learning. Although the tablets were preconfigured and the facilitators most likely extended some of their agency over the groups, the children were quite free to choose which games and especially which tasks within those games they focused their time on. A brief analysis of the data that was collected by Footsteps2Brilliance showed that some of the children did not spend any time on the parts of the game that were meant to teach them letter names and sounds. Additionally, based on brief site visits, the children showed more interest in singing along the nursery rhymes than playing the sometimes-unresponsive learning games. Collecting reliable data on the usage patterns of each tablet would have been possible by recording all screen activity, but due to the methods intrusiveness the organizers decided the study would benefit more from uninterrupted play time.

4.1. Limitations

One major limitation of this study comes from the focus on out-of-school children and the inability to randomize children into conditions that would equalize any pre-existing differences between groups. This, in turn, led to a comparison that was between children not exposed to formal learning playing learning games and children participating in traditional formal education. The out-of-school children could not be assigned to formal schools just for the sake of the study. This led to fundamental differences in the base-skills of the intervention and control group children, which in turn influenced the comparability of the results. Fortunately, such differences can be mitigated by using established statistical methods, like the repeated measures ANOVA used here.

The initial research plan focused on analyzing the differences between the intervention and control groups, but also between the different subgroups, separated by geographical location and class level. The first challenge arose when non-governmental organizations was identifying children that could participate in the experiment. Many were unable to commit to the intervention for its whole duration, and even of those that were initially able to commit, many dropped out due to their family relocating, overlapping responsibilities at home or other similar reasons. On most occasions this reduced the subgroup sizes to under 30 students, which potentially contributed to the comparisons between subgroups to become statistically insignificant.

The game, Footsteps2Brilliance, was provided to the children for free through the non-profit organization that organized the interventions. In the United States most districts offer free access to Footstes2Brilliance, however for individual children outside of the free access networks the software comes with a rather high cost of approximately 8 USD per month. Footsteps2Brilliance claims that it is being used in 42,000 classrooms, but finding data to support this claim proved unsuccessful, and the pricing schemes for these classrooms was not transparent. Therefore, analyzing the affordability of the game to support the learning vulnerable children fell outside of the scope of this article.

This purely quantitative study does not explain what else happened in the classrooms nor what happened outside of them. Discussions with the guardians of the children organized outside of the scope of this study hinted that the children's motivation to participate in the learning interventions was considerably higher than the motivation they had shown when talking about formal education. Following a similarly positive trend, the facilitators of the interventions described a positive change in the children's' confidence and their active participation in the interventions. A detailed analysis of these focus group discussions with both the guardians and the facilitators might shed light to how the interventions seemed to work through their eyes, and an ethnographic classroom study could be used to better enable the children to speak for themselves.

Finally, many of the children affected by emergencies in South-Asia share similar demographics with the children participating in the digital learning interventions of this study. However, the children studied here were not suffering from the sudden changes that emergencies typically entail. In this sense the study does not explain nor demonstrate how one should prepare digital learning environments for them to be deployable as a response to a sudden disaster that might disrupt a child's education. Similarly, it cannot consider the socioemotional burden an emergency can force on the children and their societies. Therefore, the results of this study have implications towards learning during prolonged emergencies, rather than as a response to sudden onset disasters.

4.2. Practical implications

This study offers an innovative approach to the question of supporting children's learning in challenging circumstances. The use of digital learning, and in particular, the integration of game-based learning, is an interesting alternative approach and could have substantial implications for the education of children affected by crises.

To date, there is limited evidence that supports or refutes that digital learning can be implemented in urban sums, in situations where children are affected by violence or even situations where children have no access to schools. The demographic variance of the children participating in this study enables the generalization of the results to emergency contexts, but the limited sample size reduced the power of the study and increased the margin of error. Similarly, the study is unable to address emergency specific challenges. Due to these constraints, the results of this study indicate that some basic literacy skills of early-grade students can be affected by digital game-based learning and that implementing similar interventions in sudden-onset emergency contexts could be feasible, however the study cannot prove that that digital learning games alone could pave the way to full literacy.

Outside of emergencies some of the issues that game-based learning could potentially address are the lack of qualified teachers and tendencies of existing teachers towards rote learning approaches that are prevalent in much of South-Asia. Instead of replacing teachers, including digital learning games into classrooms, and enabling teachers to observe digital game-based learning might lead to differences in the ways teachers teach. In our experiments the teachers of the interventions were substituted by volunteers from the local communities. By being exposed to learning content that was delivered though digital devices in engaging ways motivated the volunteers to contemplate playful learning methods and learning as a fun activity. Similarly, introducing digital games into classrooms might influence teachers' curiosity to alternative, playful pedagogical methods.

Although in our experiments our digital devices were fixed to certain locations, they were portable and could have been moved around to enable learning in larger parts of the settlements. The space would not have needed not be dedicated to learning, and no blackboards nor tables would be required in the same way as they are in most of traditional learning. In this sense digital game-based learning could serve as an alternative to brick-and-mortar schools when none would be available.

For children lacking access to quality education digital game-based learn solutions could help them take the first step on a journey into lifelong learning. However, further research with a wider selection of learning games and larger sample sizes is needed for a comparative analysis to better understand the effect of digital game-based learning in challenging, low resource and emergency situations.

4.3. Conclusions

In this article digital literacy tools, specifically a digital game for literacy, was evaluated based on how well they enabled children left out of school to access learning without professional guidance. The focus was on prolonged emergencies by observing refugee and out-of-school children using a digital game to enhance their learning and comparing the learning outcomes to those of children participating in national education systems. The digital learning game was selected based on its individual focus, and it offered motivating, automatically scaling learning content through colorful, interactive, and playful interfaces. The game was played on tablet computers and therefore the learning process itself did not require brick-and-mortar schools, qualified teachers nor additional books for the delivery of the educational content.

The article describes the capability of a digital literacy game to support the development a child's ability to read and write in English. It shows, like a few others before it, that technology enhanced learning is a viable solution for improving early childhood literacy skills. Unlike other studies however, the desire of this research was to explore the suitability of game-based learning for early grade literacy development of out-of-school children, whose learning was barely supported by qualified educators or existing infrastructure. The chosen environment did not only offer a potential solution for a challenging problem, but it also allowed a glimpse at using digital learning tools in relative isolation from other contributing factors.

This study found several important effects. By comparing the intervention and control groups' learning outcomes we saw that a learning game can have a positive impact on a child's ability to read, even more so than formal schooling has in similar circumstances. The digital learning resources were prepared in advance; however, the children received no prior training for using digital learning tools – they discovered and learned how to use the learning resources by themselves. This seems remarkable, considering most of the children had either no prior exposure to or at most minimal experience with mobile touchscreen devices. Like Sugata Mitra's Hole in the Wall projects, this encourages us to explore ways to independent and autonomous learning, where even young students could be expected to benefit from digital learning tools as long as sufficient access is being provided (Mitra et al., 2005).

However, children have more needs than just learning how to read. Early-grade teachers have multiple responsibilities besides instruction; they are expected to promote physical, emotional, social, and intellectual development of their students, even more so when talking about children affected by emergencies. Digital games of today are hard pressed to have meaningful impact in providing companionship and support the same way another human can.

Statement of conflict of interest

The university where the researchers either work or study covered all costs related to this research. The non-governmental organization responsible for organizing the learning interventions provided the children with the tablets, leaning spaces, facilitators and licenses to the learning game. They also allowed the researchers access to the learning facilities and facilitated activities related to data collection. Open access was funded by the Helsinki University Library.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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