"You Give a Little of Yourself": Family Support for Children's Use of an IVR Literacy System

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ABSTRACT

Low levels of childhood literacy in global contexts may be mitigated by educational technologies, however, these technologies often rely on parents of sufficient literacy to effectively support their children. Given low levels of adult literacy in many low-resource contexts, we investigate the nature of low-literate adult support for children's use of a literacy technology designed to foster early literacy precursors. We deployed an interactive voice response (IVR) system with 38 families in a rural village in Côte d'Ivoire using the IVR for 5 weeks in their homes. Using call log data and grounded theory analyses of IVR observations and interviews, we find evidence that families leverage complex support networks where family members support children's use of the IVR in different ways, via a collective network of intermediaries. These results suggest opportunities to scaffold low-literate family supporters for educational technologies.

KEYWORDS

HCI4D, IVR, literacy, ed tech, tech intermediaries

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1 INTRODUCTION

Low rates of childhood literacy present barriers for future educational attainment and economic productivity in contexts across the world [30, 35]. Prior research has shown that a stimulating home literacy environment is critical for fostering children's literacy [32, 55], but in many low-resource contexts, particularly those in which adult literacy is low, children may lack such resources in the home environment. To address this, literacy instructional technologies have been deployed in many low-resource contexts [62], leveraging increasingly ubiquitous mobile devices [34]. However, much of this prior work is often targeted at the child alone [26, 28, 45], without leveraging the critical support of other family members [30, 55]. Or, when they do involve adults, they require sufficient literacy to read SMS messages [14, 64] or help with literacy instruction (e.g. book reading, letter naming) [49].

Voice-based systems, such as interactive voice response (IVR) systems, have been designed and developed for low-literate users in low-resource contexts, for applications such as agricultural information [46], grievance redressal [38], and community media [42]. However, such systems have largely focused on information-seeking for adults, not educational applications for children, and are largely designed for single end-users, rather than engaging parents or other family members in providing critical literacy support [55].

This paper is part of a larger research program investigating the role of a voice-based intervention in fostering phonological awareness (a critical precursor for children's

literacy development [17]) in low-literate, low-resource contexts. We are working in rural communities in Côte d'Ivoire, where adult literacy rates (55% for men and 35% for women [35]) lag behind regional and global averages. In prior work, we elicited preferences, values, and design guidelines for literacy ed tech from similar communities [37]. We have designed an interactive voice response (IVR) system, Allo Alphabet, to foster phonological awareness in French, and we report here on an initial deployment of Allo Alphabet.

We intend for this paper to contribute at the intersection of information-communication technology for development (ICTD) and human-computer interaction (HCI), by identifying how family supporters of a variety of literacy levels contribute to children's learning with a literacy IVR. Using call log data, call observations, and interviews, we find evidence that families leverage complex support networks where family members support children's usage of the IVR in different ways, via a collective network of intermediaries, and we suggest design opportunities to scaffold such support.

2 RELATED WORK

The Social Ecology of Home Literacy

Significant research on the science of learning suggests that learning in the home environment is an essential complement to the literacy development that continues at school [12, 32, 55], through the critical role that parents and other family members play in literacy acquisition [30, 32, 55]. Parents may provide *explicit instruction* of letters and book-reading [18], *motivational* support by providing a secure socio-emotional environment for children to take risks in learning [30, 48], *dispositional* support by communicating to children that literacy-building behaviors have value [7, 48], and *metacognitive* support by maintaining children's attention and scaffolding self-regulation [30].

However, parents with low or nonexistent literacy, or literate parents who are not literate in the target language their child is learning, may be less likely to provide explicit support for children's literacy [16, 20, 31, 61]. Parents are not the only members of the home environment who impact children's literacy development, however. Some have argued that families with more children have worse educational outcomes for all children, due to the "resource dilution" hypothesis (e.g. having fewer resources [time, money, etc] to devote to each child) [15], while others posit that older siblings might play a mentorship role for younger children [19, 39]. It is thus not clear how other family members might impact children's literacy, particularly less literate family members.

Mobile Literacy Technologies

Given the ubiquity of low-cost mobile devices in low-resource contexts [34], and evidence suggesting that adaptive learning technologies may be an effective means to improve educational outcomes in developing contexts [8], there have been many literacy interventions designed for mobile devices [62], with some using tablets [58] or e-readers [53]. For instance, Ojanen et al. developed a smartphone app to help children recognize phonemes [45], and Kumar et al., developed voice-controlled literacy apps for rural India, [28].

However, despite the importance of the home literacy environment, with few exceptions [49], the majority of these systems focus on the child as the sole learner. To support home literacy, some researchers have built interventions to engage parents, such as sending reminder messages to teach letters or read stories [14, 49, 52, 64]. However, substantial prior work suggests that parents' engagement with their children's education is strongly associated with their literacy [61] and socio-economic status [16]. It is thus not clear how effective such interventions will be with low- or non-literate parents in a rural, low-resource context.

Designing for Low-Literate Users

In low-resource contexts, voice-based interactions have shown promise in engaging low-literate users [41]. Existing approaches to voice-based interactions have primarily focused on either speech recognition-based systems, as in the SMART system [28], or interactive voice response (IVR) systems, which we focus on here due to their accessibility for low-cost basic mobile devices. IVR systems have been widely studied for their effectiveness in engaging low-literate users [33], as in work on agricultural voice forums [46], grievance redressal [38], social networks [51, 59], community media [42] and community radio [25] and even broadcasting information about Ebola through viral spreading [63].

However, prior IVR systems have largely been designed for adults seeking information or entertainment, and not for educational applications for children. Further, as in research on mobile literacy systems, the majority of IVR systems primarily target a single end-user, rather than designing for parents or other involved family members. Other work on designing for multiple low-literate users, however, *has* explored the role of technology "intermediaries" who assist the primary user in operating information technology [23, 24, 44, 54]. For instance, Sambasivan et al. identified design considerations for low-literate users who rely on intermediaries to help read and understand information on their mobile devices [54]. However, prior work on tech intermediaries focuses largely on the intermediary providing information to the user, and thus does not shed light on the role of intermediaries in a learning context, where the active role of the learner is critical for learning [27]. For a literacy system, parents or other family members may want to support their children, but may lack sufficient literacy to be an intermediary.

In sum, while prior work has developed mobile literacy systems to support children's literacy development in low-resource contexts, and developed IVR for low-literate adults it is not clear how children will use an educational IVR. Secondly, while prior work on tech intermediaries highlights the role of literate users' support in helping low-literacy users access information through digital interfaces, it remains unclear exactly how low-literate users may act as an intermediary for their children's use of an educational IVR, particularly given the importance of family literacy support.

To address this, we investigate the following questions:

RQ1: (a) What are rural Ivorian children's patterns of use of an IVR literacy system designed to foster the development of French by building phonological awareness and decoding skills? (b) What is the relationship between their usage of this IVR and their performance on the IVR lessons?

RQ2: (a) How do rural Ivorian families support their children's use of an IVR literacy system? (b) What is the relationship between that engagement and children's IVR usage?

3 METHODOLOGY

This study is part of an ongoing research program [21, 22, 37] on supporting literacy in cocoa farming communities, conducted by an interdisciplinary team of American and Ivorian psychologists, linguists, economists, sociologists, and computer scientists, in partnership with the Ivorian Ministry of Education since 2016. In this section, we describe the design and initial deployment of an IVR literacy system we developed to foster phonological awareness, Allo Alphabet.

IVR Literacy System: Allo Alphabet

Because many families in rural Coôte d'Ivoire are low-literate [22, 35], we designed and implemented an early literacy curriculum on an interactive voice response (IVR) system, Allo Alphabet. This follows many others [38, 41, 46, 50, 51] in using IVR for low-literate users. Our system provides instructions, questions, and feedback via voice messages recorded by an Ivorian researcher, with answers input via touchtone (DTMF). The users call in to a specified number, which immediately ends the call and calls the user back to avoid fees for the users. For this study, airtime costs were subsidized by the research team; future work may explore alternative solutions for more sustainable access (Cf. [60]).

Language and Literacy Curriculum Design. Prior research demonstrates the importance of phonological awareness to early literacy development, as the understanding that language is built from sounds and syllables is critical for the ability to map sounds to print (i.e. decoding) [4, 29]. In this curriculum, we target phonological awareness and print-sound mapping, gradually increasing in complexity and difficulty, from simple phoneme and syllable awareness, to mappings between letters, words, and sounds. In this study, users only experienced the first 2 of 8 units, which ask learners to match words or syllables that share a sound or a combination of sounds, to choose the word or sound that "does not belong", and others. At the start of each call, the system plays a welcome message, updates the user on their progress, and selects the next lesson based on the user's prior mastery of concepts. Each lesson begins with an explanation of the concept in that lesson and an explanation of how to respond. For each question, the system plays a pre-recorded audio message with the question and response options. Questions have either two or three responses, depending on the type of question, with most questions having three options. After responding, students receive feedback on their responses. If incorrect, they receive the same question again, with a hint message explaining the concept or prompting the student to focus their attention on a particular part of the word or syllable. After one or two wrong attempts (depending on the question type), the answer is provided, with a brief explanation.

Device Description. In prior work [37] we learned that many families in rural communities in Côte d'Ivoire possess mobile devices already, with some families having multiple devices per family. However, for this study, we provided a mobile device and SIM card to participating families for the duration of the study to enable more consistent access to the system and a more consistent experience of the content for all users. We chose the Itel IT5231 mobile phone, a model available in stores in the Adzopé region and which would likely already be owned by others in the village, who could provide additional support if needed. It has a loudspeaker for playing voice messages hands-free, and 2G network accessibility, which is available in most of the Adzopé region [34].

Study Design

To investigate our research questions about how children and families use an educational IVR, we deployed Allo Alphabet with 38 children for 5 weeks, and collected quantitative data of children's system usage, as well as qualitative data of observations and interviews with 24 children at home.

Study Context. This study took place in a rural village in the Adzopé Department, a cocoa- and rubber-producing region in southeast Côte d'Ivoire. The study village had a population of 13,786 as of the 2014 census [9, 10], with speakers of Attié, Koulango, and Dioula, in addition to French. Located along the main highway from the regional center of Adzopé, there is regular foot traffic and private buses and vans that provide the main source of transportation between this village and the surrounding area. Schools in the Adzopé region have a student-teacher ratio of 45:1, and many schools lack electricity, water, or bathrooms [9]. This study was approved by the IRBs of participating universities, as well as approved

by the review board of the Ivorian Ministry of Education. We met with the head of the local COGES (*Comité de Gestion d'Écoles*, or school organization committee) and village chief to obtain approval for the study and align our methods with local norms. The study took place with 38 of the 39 students from the CM1 class (equivalent to 5th grade in the US) in one randomly chosen school of the four public schools in the village. We held a meeting with parents and guardians of the CM1 students to explain the study and obtain consent to participate. We met the parents at the school, as it was a central meeting area, and the school directors assisted us in meeting parents at the school. However, we explained to parents that the study would take place at home, and they were not required to participate. The study lasted for five weeks, from October 25th to December 1st, 2018.

Assessment, Survey, and Phone Training. A pretest was administered at the start of the study to establish a literacy baseline. The pretest included items on phonological awareness in French and Attié, the primary local language, such as identifying the initial or final sounds of words (e.g. "jour /j/"), removing the initial or final phoneme of words and identifying the subsequent word (e.g. "neuf - /n/ = oeuf"), and items on phoneme and syllable segmentation. The test also included a basic assessment of French reading skill through grapheme identification (e.g. "what is the name of this letter or group of letters? "ch"), reading common words (e.g. "mal"), and reading invented words (e.g. "tipa"). Prior to the start of the study, we gave a one-hour training for caregivers of all participants, explaining the purpose of the study, distributing the phones, and teaching them how to call and complete lessons. Though we showed the adults how to call, we did not explicitly instruct them to assist their children.

During this seminar, we also administered a brief survey to understand more about participants' home environment, such as family members' occupations, literacy, proxies for socio-economic status, and more (not all of which are reported on here). The primary employment of most families in the study was cocoa farming (26/38), though there were also sellers of fish or vegetables (7/38), two tailors, a teacher, and a cocoa distributor. These families were distributed across the village, with some located quite near the school, and others several kilometers away, with some living in minority language communities, such as Koulango and Dioula. Most families spoke French in addition to their mother tongue, though two spoke only Attié and two only Koulango.

Home Observations and Interviews. Our team of an HCI researcher and a linguistics graduate student from Coîe d'Ivoire who spoke several mother tongues visited 24 participants at their homes for 3 of the 5 weeks of the study, to observe how the children and their families used the IVR. We called each family to schedule a time to visit, and only 24 (of the 38 participants in the study) were available. Half of the observed participants were boys and half girls. During the visits, we interviewed an adult guardian and observed the children calling the IVR. We interviewed 19 adults in total, for 24 children, as some families had multiple children participating.

In each visit, we explained that we wanted to observe the normal scenario of calling and completing the lessons, to the extent possible, though there was likely some effect of the two researchers observing. We took careful notes (and recorded video) of how the child used the system and how the adults present interacted with the child. We asked the adults questions about how and why they helped their child learn - in ordinary circumstances as well as with the IVR - and questions about their beliefs and goals about education and French literacy. Each interview and observation was nearly an hour, totaling nearly 20 hours of video data.

Qualitative Data Analysis

Because we did not have *a priori* codes, we adopted a grounded theory method for the qualitative data analysis [6, 43, 57]. Grounded theory is an iterative thematic analysis approach to emergent sense-making from data, with four levels of analysis: beginning with open coding of the raw data, then generating axial codes that capture a more abstract representation of the data, then organizing those axial codes into a set of categories, which, finally, are summarized by "core categories" [57]. Three of the authors thus coded the video observations and interview transcripts and discussed our emerging themes, synthesizing the emerging codes as necessary to arrive at what is referred to as theoretical saturation, or the point at which our data is fully described by our codes [57]. Throughout the data collection process, we conducted regular debrief sessions with our interpreters and other collaborators from the region to help resolve questions about concepts that arose during the interviews, what Brown et al. describe as "peer debriefers" [5]. These discussions were primarily about emerging conceptual themes and other questions we had. We recorded these discussions as voice memos and field notes, and returned to the memos during the coding process to update our codes and triangulate them with other data sources, as part of a "constant comparison" (Cf. [6, 57]).

4 CHILDREN'S USE OF LITERACY IVR

To investigate children's use of our IVR literacy system, Allo Alphabet (RQ1a), we used call detail records logged for all interactions of 36 users for the five weeks of the study (1 phone was used by two children, and we thus removed those participants from these analyses). We find that each student called in for a mean of 14.2 days (SD=7.4) of the 38 total days of the study, with one student initiating calls for 32 days, and one calling for only one day. On average, users initiated 81.4 calls across 5 weeks (mdn=68.5, SD=59.6, min=1, max=337).

The usage was relatively constant during the week, with a slight increase on Fridays, averaging 104.2 calls each Friday (*mdn*=67.0). On all days, the majority of calls were around 6-7pm (GMT), though students did call in throughout the day, from 6am until 10pm (Figure 1). On average, students spent 6.2 minutes on the calls (*mdn*=4.9, *SD*=4.3), with one student spending an average of 1.2 minutes and one with an average of 20.4. Across all calls, users attempted an average of 302.4 questions (*mdn*=193, *SD*=233, min=3, max=890), and correctly completed 44% (*SD*=6%, min=33%, max=62%) of the questions on the first attempt (as hints are given on later attempts). If students would have guessed randomly, they would have been correct 37% of the time.

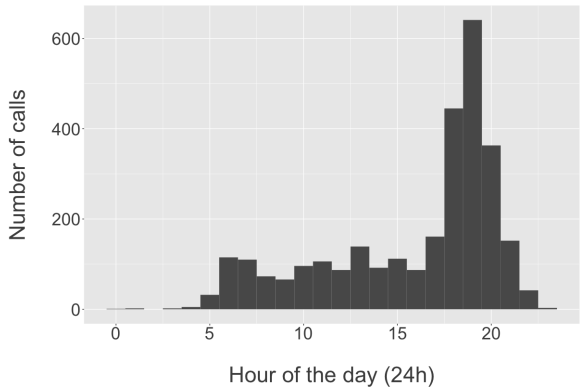

Figure 1: Distribution of IVR call times

To investigate the relationship between children's usage of Allo Alphabet and their phonological awareness (RQ1b), we use two features from the call detail record data (call frequency and call duration), as well as their performance data on the pre-test and the IVR question items. We conduct two regression models with students' percent of questions correct on their first attempt as the dependent variable and with their pre-test as a covariate for both. For one model, the total number of users' calls to the IVR was the independent variable (IV), and for the second model, the IV was the duration of calls to the IVR. There was no significant correlation between the IVs used in each model. We hypothesized that students who called more and students who spent longer on the calls would answer more questions correctly, particularly for students with a greater score on the pre-test.

We find that there is a significant, positive relationship between the total number of calls a user makes to the IVR and the percent of questions they answer correctly on the first attempt ($F(3,30)=1.41$, $p<0.05$, adj $R^2=0.04$). That is, children who made more calls answered more questions correctly on the first attempt. However, no direction of causality is intended by this formulation. It may be the case that children who answered more questions called more. For the second model, we find that there is a significant interaction effect between the duration of the IVR calls and users' pre-test score, on the percent of questions they answer correctly on the first attempt ($F(3,30)=3.56$, $p<0.005$, adj. $R^2=0.19$). Students with a lower pre-test who spend longer on the calls answer a greater percentage of questions correctly on the first attempt than students with higher pre-tests (see Figure 2).

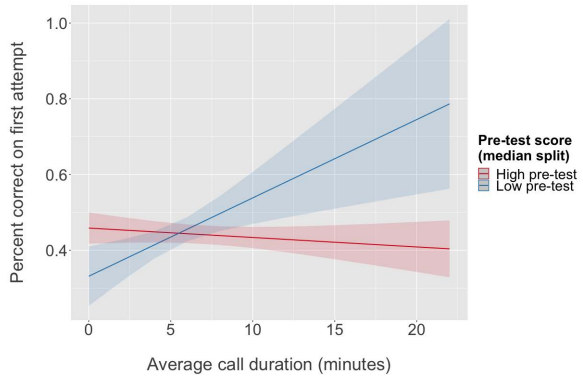

Figure 2: Interaction effect of pre-test and call duration

5 FAMILY SUPPORT FOR CHILDREN'S IVR USAGE

From the home observation and interview data, we identified several key insights about how children use the IVR at home. At a high level, we find that many children in our study had support from other members of their family in using Allo Alphabet. Of the 24 participants we observed and interviewed at home, we saw family members of 17 of those participants providing support during the lessons, 14 of whom explicitly told us that this support was provided regularly during other times they used the IVR. The remaining 7 participants told us that no one else at home provided support for the IVR, with some of those telling us that there was no one at home who *could* help them if they needed it. For children with support from other members of the family, we find that (1) many of these families leverage support networks with distributed roles and responsibilities for supporting their children's use of an educational IVR; (2) these adults provide various types of implicit and explicit support for children's literacy learning with an IVR, and (3) children in families with adult support attempt fewer questions, but answer more of them correctly than children without such support. We discuss each of these in more detail in the following sections.

Family Support Networks

We find that many **families leverage complex support networks** for their children's learning, with different support roles played by different family members at different times. These support networks were often comprised not

only of the children's parents (13/24), but also other adults such as the aunt (2), uncle (2), and grandparents (1) who lived in the household or nearby, and older siblings (6) or near-peers (2), and occasionally adult neighbors (1). In our pre-study survey of all 38 participants, 32 of 38 children reported having someone in the family who can read, but only 12/38 reported that one of their *parents* could read. 26/38 said one of their siblings could read, while 15/38 said one of their extended family members could read.

These support networks involve a variety of different supporters, who have a variety of motivations for calling the IVR and providing support, leveraging a range of skills and literacies. In part, we find that these family supporters help due to a sense of responsibility for the child's welfare and development. As several adults told us, they are helping "for their [sibling's] good tomorrow" (P11, older brother) and so that "they will be able to evolve, to know many things" (P16, aunt). We find that families construct and leverage these support networks to **compensate for gaps in other sources of support for their children's learning**, due to limitations in availability or literacy of other members of the family. As several participants described, their work in the fields required that adults leave home for several days at a time: "There is no one here. His sister is in Adzopé. Everyone goes to the field, and we are only two here." (P8, mother).

Although we heard from a small number of parents that they paid for a home tutor (*mâitre du maison*) to help with schoolwork at home (as we saw in our previous work in this region [37]), here we saw evidence that **older siblings took on informal tutor roles** to help with the IVR lessons, either because the family did not hire a tutor, or the tutor did not help with the IVR. We observed direct evidence of these informal sibling tutors in 6 observations, and were told about informal sibling tutors with 10 others, of the 24 participants observed. One sibling tutor told us that he began helping with the IVR lesson because the home tutor was unavailable, saying "It's not like I know anything about it, but since their tutor is not there... you have to [use the IVR] in front of me" (P11, older brother). This sibling tutor acknowledges that in spite of gaps in his own knowledge, he is helping with his siblings' IVR lessons. These sibling tutors worked either one on one or with groups of children, in some cases from multiple families (Figure 3). "He is my nephew. She is my neighbor's child. Since it's not far, I said they just have to come here." (P11, older brother). These family supporters describe helping in spite of limitations in their literacy. Several of these supporters described their difficulties, saying they had trouble with "Words that rhyme, words that do not rhyme. It's there that I got stuck" (P4, older sister), while others want to help "with the little that I know" (P16, aunt).

In light of this evidence that even the designated helping adult may not have a complete mastery of the content, our

Figure 3: Adult working with a group of children

participants articulated a philosophy of **mutual support and bootstrapped knowledge sharing** among members of the family. Many adults (10/19) described how others in the family help their child use the IVR because adult family supporters believe in the importance of sharing knowledge with others. One mother said, "because if you do not understand [something], the other could." (P7, mother). Similarly:

> What I do not know, you [might] know. What you know, the other does not know, and you give a little of yourself. He can know [question] one, but he does not know [question] two, and you might know 2, but you do not know 1. If I show you, you show me. (P11, older brother)

These adult supporters articulate a philosophy for mutual support, where one can "give a little of yourself" to help others and compensate for one's lack of knowledge by learning collaboratively. In fact, he later told us how his youngest brother, the participant in the study, was the one who initially showed *him* how to use the phone to dial the IVR. In other families, this collective support from others took the form of near-peers assisting the adult in teaching the participant, either helping the adult hear and understand what the IVR is saying by repeating it aloud for the adult, or helping the adult write content on the chalkboard. One mother told us how her son (only one grade above the participant) helped her daughter learn with the IVR, because "he's stronger than me. Because I left school a long time ago." (P10, mother).

Although other members of the family may support the child using the IVR, these **family members are not always consistently available to support**, occasionally limiting children's access to the IVR entirely. We heard from one child who told us that she never used Allo Alphabet alone, but the sister she normally worked with was often in Adzopé (P14, participant), and her parents would not let her use the IVR without her older sister. This was echoed by another child who told us that the person who helps her with the IVR goes to school in Adzopé, and is only home on weekends

(P5, participant), so she only called on weekends. In other cases, sometimes even if the adult was present and available, they told us they might be too tired after work to help (P9, mother), or they may have other responsibilities that impact their ability to focus on the child with the IVR, such as caring for younger children or preparing dinner, which we observed during multiple sessions. As one mother described, "If on the working days she needs help during my cooking time, she will sit and continue by herself" (15, mother).

Methods of Adult Support for Children's IVR Usage

From observations of 24 children using the system at home, we identified several key ways in which adults support their children's use of an IVR literacy system at home - they (1) structure and arrange the conditions for learning; (2) provide explicit instructions for using mobile phones; (3) model and guide children in using the IVR; (4) provide explicit literacy instructions; and (5) offer socio-motivational support.

For some (10/19) parents, one major way they support their children's use of an IVR literacy system is by **structuring the context and environment for their children's learning**. For some, this involves the adult deciding when and where children should call in for the lessons, reminding children to start the lessons for that day, or telling them when to finish the lessons. Two children did tell us they were the one to decide when they used the phone to call for lessons, but this was a rare exception (2 of 24 children). Others made sure the environment was conducive to learning. In many sessions, there were large numbers of other children nearby (M=4.3, SD=3.2, max=12). Although this may have been due to our presence as guests, when we asked, many of the adults told us this was normal. To mitigate these distractions, adults would quiet the younger siblings, wave other children away, or keep other children occupied during the lesson to not distract the child using the IVR. For families where this did not occur, we observed children struggle to hear the recorded voice of the IVR in often-noisy environments.

In addition, adults support their children's use of an educational IVR by **providing explicit support or control of the mobile phone**. In our preliminary survey, we found that all 38 families owned at least 1 basic phone (M=2.2, SD=0.76, max=3), with 3 families owning a touchphone in addition to their basic phone(s). Several (7/24) children told us that they had previously used their parents' phones, mostly for games or calling other family members. In this study, we find that adults often supported IVR usage by turning the phone on, finding the contact for the IVR in the contact list, dialing the IVR, answering the callback, and occasionally turning on the hands-free speaker. Some adults (7/19) dialed the IVR themselves, and then passed the phone to the child to respond to questions, while others (5/19) allowed their child to dial, but took the phone back to re-dial it if needed. Thus, even for family members with low French literacy, some support their children by helping dial the IVR number.

In addition to the mobile phone support, some adults supported by guiding children on how to effectively **listen and respond to the IVR lessons**. While some children appeared to listen thoughtfully to the IVR instructions, questions, and answers before responding, others appeared not to listen before responding. Some children (4/24) pressed the button to respond before all the answers had been listed. To address this, adults guided their children in listening carefully to the lessons (10/19), with some adults telling children to listen, think about the response options, and then respond, saying "Listen carefully; understand first before pushing. Before you press you have to listen." (P11, older brother). Many other adults echoed this admonition to "Listen to what she [the recorded IVR voice] tells you, listen carefully." (P12, father). Other adults started by listening to instructions and questions themselves, either holding the phone to their ear, or directing their child to put the phone on hands-free so they could hear, as in one father who told his daughter that "we too will listen to what she says" (P12, father). We observed many other adults modeling this type of focused listening by sitting with their child and leaning in closer to hear the IVR voice. In some cases, the adults guided their child's listening on the phone using nonverbal cues, such as motioning them to put the phone to their ear, or putting their hand on their child's arm to indicate they should wait to respond.

Adults also prompted children to respond, either by pressing the response button, verbally repeating the answer to the adult, or even, in some cases, writing the correct responses on chalkboards. We observed one father tell his daughter, "You have to listen carefully. Which one is the right answer among these three words?" (P12, father). On some occasions, the adults would repeat the questions to make sure their child heard it, and would prompt their child to repeat the question. In some cases, the adults would write the response options down, either on a chalkboard (e.g. Figure 4), on paper, or with a stick in the dirt. While less frequent than other types of support, some adults (9/19) provided **explicit instrumental support** for the IVR lessson content. One sibling tutor told the two children with her to turn off the IVR, wrote three response options, and asked them to say which word ended with "ar" (P4, older sister, Figure 4). However, this requires that the adult be sufficiently literate herself, and to choose the right concepts. One sibling explained the concept of multiple choice questions (names anonymized):

> *Tutor*: If I say between "N'Guessan" or "Blanche", between one or two, which one is Blanche? *Blanche*: Two. *Tutor*: Good job, you did well. (P11, brother)

To elicit this instructional support, some children directly asked their parents or adults for help with the lessons, while

Figure 4: Older sister writing examples on a chalkboard

for others the **adults offered this help without being asked**, when the child appeared to need it. We observed some children handing the device over to the adults for support, both for IVR and for lesson support. One older sister told us how her siblings asked for her help, saying, "They force me to come to the phone, because nobody understands." (P4, older sister) However, not all children asked for help, even with an adult sitting next to them. One adult told us she helps "when she has a worry or... when you see that it's too hard for her or she repeats... it's when she's stuck that we help her" (P10, mother). However, this requires that the adult is present during the lesson and able to hear and understand the negative feedback provided by the system, which may not always be the case. **Adults also offered encouragement or motivation** to children as they progressed through lessons. An older sibling echoed this, saying, "I'm not going to teach them every night, but I encourage them. In fact I'm a support, from one point of view." (P11, older brother). For him, his role as "a support" involved providing encouragement.

Effect of adult support on IVR usage and learning

Finally, given all of the different ways that adults provided support, we wanted to investigate the effect this support might have on children's IVR usage (RQ2b). To investigate this, we created a binary variable of whether each child was one of the 14 participants who we observed with adult support during the IVR lesson, *and* who told us that this support was regular and consistent for the previous lessons - or whether they were one of the 6 participants who we observed with *no* support during the lesson, *and* who told us that they had no one who they could get support from (4 participants did not meet either of these criteria). We hypothesized that children with family support would call more often and would perform better on the questions than children without such family support. However, there was no significant difference in the number of calls children made to the IVR in families with (M=100, SD=76.9) and without (M=94.5, SD=49.5) adult support ($t(15)$=0.22, p=0.83). There was, however, a large, though non-significant, difference in the number of questions attempted by children in the two groups, with children in families who we observed with support attempting fewer questions (M=295.6, SD=239) than those without observed support (M=457, SD=282.9), $t(8.2)$=1.22, p=0.26. This may have been due to the supporters taking time to explain the concepts in the questions, time which children without such support spent attempting questions. Finally, children in families *with* support correctly completed a greater percentage questions on average (M=0.47, SD=0.07) than those without such support (M=0.43, SD=0.03), though this difference was not significant ($t(17.9)$=1.86, p=0.08).

6 DISCUSSION

In low-resource contexts with low adult literacy, educational technologies may offer one opportunity to address gaps in children's literacy that may impact their future educational attainment. However, such systems are often designed for the child alone [26, 28, 45], without explicitly engaging the adult caregivers or others in the home environment, or they require adults be literate to support their child's use of the system [14, 49, 64]. In contexts where many adults may not be literate themselves, or where adults' support for literacy may look very different from parental support previously identified in Western contexts (Cf. [30, 32, 55]), educational technologies should be designed accordingly.

This study is part of a larger research program investigating how to design ed tech interventions to support childhood literacy in low-resource rural contexts. In our prior work in rural communities in Coûte d'Ivoire, we identified adults' motivations and preferred methods to support children's literacy [37]. In this study, we designed an IVR system to foster children's phonological awareness, Allo Alphabet, and deployed it with 38 participants in one village in rural Coûte d'Ivoire, for 5 weeks. Our goal was to understand how children would use an educational IVR, and how families would support children's IVR use. We find that many participants called in regularly to respond to questions, with their correctness on those questions positively associated with their amount and duration of calls (though, interestingly, *not* their prior knowledge as assessed on the pre-test). We find that the majority of participants we observed used the IVR with support from other family members, and children who had such support correctly completed more questions on average.

Distributed Educational Support Networks

Prior work on early literacy at home often focuses exclusively on the role of the parents [30, 32, 55], and presents conflicting hypotheses for the benefits of other family members (e.g. siblings) on children's literacy [15, 19, 39]. In contrast, we find here that families in rural communities in Côte d'Ivoire

often leverage support networks of multiple adults and siblings (i.e. not only the parents) to support children's literacy with an IVR. In fact, this idea of leveraging other family members to support children's literacy was echoed in our prior work in the Adzopé region, where parents told us that, in their families, everyone contributes to support children's development [37]. In this study, we see evidence that this is not only a value held by parents, but it is enacted in the lives and practices of families using educational technologies.

While many parents in our study did not have sufficient literacy themselves to support children's literacy in the explicit, instrumental ways described by prior literature - such as letter naming, book reading, etc [18, 32, 55], parents leverage multiple actors in their family network to support their children through a variety of literacies, both print and digital. These supporters often provide other types of support beyond instructional content support - from structuring the conditions and environment for learning, communicating the value of literacy, and procuring resources (e.g. chalkboards, notebooks, and private tutors), to teaching children how to use the mobile phone and IVR. This echoes what Barron et al. and DiSalvo et al. describe as the multiple roles that parents play in their children's learning, such as learning brokers, resource providers, and monitors [1, 13]. However, unlike prior work, we see here that these roles are not played only by parents at different times, but in our context are distributed across multiple actors in family support networks.

We did not find the hypothesized positive relationship between children's prior phonological awareness (as assessed on the pre-test) and their successful completion of the language lessons on the IVR. This suggests that there may be moderating factors at work, such as children's ability to operate the phone or understand how to respond to IVR questions, or other differences between the pre-test and the IVR items. We observed many children who responded to questions before the responses were listed, or who were unsure how to answer a multiple choice question. To address this, **many family supporters provided device and IVR support**, helping children call the system, and helping them understand how to press the touchtone to select responses to multiple choice questions. The support for device and IVR usage (broadly, digital literacy) may thus have contributed to the increased question performance for children with adult support compared to those without it. Many supporters who were not themselves literate were observed using their own mobile device for calls, as well as recognizing and selecting the Allo Alphabet contact in the children's phones. In fact, while the adult literacy rate in Côte d'Ivoire is less than 50%, mobile phone penetration in Côte d'Ivoire is over 130%, with every family in our study owning at least one phone.

This suggests that, unlike prior work that found that literate intermediaries help low-literate users operate mobile devices [54], here, we see that digitally literate adults may be able to support children's mobile device and IVR usage, despite lacking the French literacy knowledge to help with the content. However, not all adults in the study provided digital literacy support, despite the potential for them to do so. This suggests design interventions to nudge adults to support their children in using the phone or IVR if it appears from the log data that the child is having difficulty using the IVR appropriately (e.g. pushing numbers that are not options, or responding before the audio is complete).

However, while these family support networks provide flexible coverage on various support roles, they may introduce **communication and coordination challenges.** These support networks are complementary, distributed, and flexible, with adults taking on support roles due to gaps in support from others in the family. This flexibility is in some cases a strength, as when older siblings take on informal tutoring roles when the formal tutor is unavailable. However, there may be breakdowns in the communication among these family members, potentially impacting the uptake of the system. For instance, when some families sent an adult to the initial launch of the study to be trained how to use Allo Alphabet, this adult in some cases did not tell the other adults at home about the purpose of the study or how to use the IVR. Some families thought the phone was a gift for their child performing well in school, while others did not know that it was meant to be used for calling to receive lessons. For some families with communication issues, the adult who attended the information session simply failed to tell the parents about the purpose of the study, while others tried to inform them, but weren't able to explain how to use the IVR.

This suggests that scaffolds for adult support for children's educational technology usage should account for the potential to have multiple supporters, operating asynchronously, who may not communicate among themselves regularly. This might entail sending SMS or automated voice calls to each supporter who is associated with the child, or prompting them to communicate with the other supporters in the family in other ways, such as radio broadcasts or use of the town crier (*griot*). Further, as some adults might be better able to support the child in different ways, designers of adult support scaffolds might infer or detect the type of adult supporter (e.g. supporter for device or IVR usage, supporter for instructional content) based on their patterns of activity, and suggest personalized support based on that role.

Collective Intermediation in Educational Technology

Prior research on technology use in low-resource, low-literacy contexts has highlighted the role that technology *intermediaries* play in supporting the primary user, or beneficiary, in their use of technology [23, 42, 54]. We find evidence in this study for a **collective approach to intermediation for**

educational IVR, through family support networks where supporters may not be more literate than the beneficiary user, but where each person supports in different ways, via this collective network of intermediaries with different skills. The members of these family support networks describe being motivated out of a sense of shared responsibility for the primary user, not for reputation or social capital (as in [54]), and they balance between active and passive support roles as needed, rather than the primarily active role of intermediaries for information-seeking technologies [23, 42, 54]. These findings mirror prior ethnographies of care and support in Côte d'Ivoire, which identified how families develop mutual support networks for family members with health or financial difficulties [3, 36]. This suggests design opportunities for leveraging collective, distributed intermediary support for other sectors, such as family health [2, 47] or finance [40].

Although the Allo Alphabet IVR was designed for a single user, adult supporters adapted their usage of it to fit their desire for collective support for children's learning, much like other ICTD work on users' appropriation of technologies beyond the intended usage [56]. We find that **adults engage in both simultaneous and sequential use of the IVR with their child**. We heard from many families who valued children learning collaboratively, and we saw cases where the adult worked with multiple children at the same time, either sequentially, with children observing the others using the system while waiting to call in themselves, or simultaneously. These simultaneous learning scenarios meant the adult could direct a group of children's attention towards a shared resource (often a chalkboard) to provide instructions to all. Unfortunately, the IVR audio often continued playing in the background, which was potentially distracting.

This suggests that designers of educational IVR may benefit from designing affordances for the potentially collective nature of learning at home, with multiple learners using the system in the same place sequentially or simultaneously, and possibly in the presence of an adult supporter who may support the IVR usage synchronously or asynchronously via offline instruction. The adults in this case might also play a co-learner or collaborator role [1, 13], where they may develop their own literacy abilities by scaffolding children's responses to questions. In addition, for adult supporters with sufficient literacy to provide instructional support (as in the sibling teaching the rhyming skill on the chalkboard), the types of skills and example words the adult chooses to teach may not be what their children actually needs the most support with. An educational IVR might thus provide messages to the adult supporters with personalized support suggestions. Further, given the challenges of simultaneous engagement, educational IVR might provide asynchronous components to support offline activities or games, to leverage the benefits of collaboration while not distracting children with simultaneous audio messages, or allowing the adult to pause the IVR while they provide offline support.

Limitations and Future Work

Although we observed our participants use the IVR in a natural setting by visiting their homes with a local collaborator, our findings might be limited by *participant response bias* [11], or a potential selection bias, as the remaining 14/38 participants were not available. However, there was no significant difference in frequency of IVR usage for the 24 participants compared to the other 14. We also do not know whether the person responding to the IVR lessons was the intended participant, their adult supporter, or other children. While we have log data from 5 weeks of system usage, we only conducted one observation and interview each with those 24 participants, and thus we do not have longitudinal data on the nature and extent of support provided over time. The binary categorization we used here for whether children had support or not is a fuzzy category at best, as this support may have been inconsistent before or after our visit. While an isomorphic post-assessment would be the ideal method to show growth in learning, complications from school holidays and teacher strikes rendered us unable to deliver a post-assessment in a timely fashion. For future work, we plan to conduct a longitudinal study to measure the learning gains in literacy from the IVR over several months (with an isomorphic post-assessment delivered at the end of the intervention), and with a version of the IVR to provide suggestions and scaffolds for adult supporters, which will also provide us with a quantitative measure for adult support.

Conclusion

Educational technologies offer one approach to foster children's literacy development in out-of-school contexts, but if these systems continue to be designed solely for the child, or rely exclusively on literate parents to help, they will miss out on the rich support networks that families construct to help their children. Voice-based educational systems may provide an opportunity to leverage such support from adults of all literacy levels, but these systems may not be designed to engage these supporters effectively. We intend for this paper to contribute to the community of researchers designing educational interventions for low-resource contexts, by identifying ways in which family supporters of a variety of literacy levels may contribute to their children's learning. In this paper, we find further evidence for the complex, multifaceted role that families play in supporting their children's learning, we identify specific ways in which adults support children's use of an educational IVR system, and we suggest potential design recommendations for designers of educational systems that may engage family supporters.

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