Chapter 38
Design and Evaluation of a Mobile Application for Interactive Reading

Jose Andrés Mejías, Christian Quesada-López, Alexandra Martínez, and Ana M. Carmiol

Abstract Interactive reading of children's books is one of the most effective methods for promoting language development in children. However, there are barriers for low-income families to purchase children's books. Therefore, we propose a mobile application that supports interactive reading between caregivers and young children, thus facilitating access to children's books for those families. This work reports on the design, development, and evaluation of the mobile application prototype. The mobile prototype was evaluated by six experts in interactive reading and the results suggest that our prototype can effectively support this process. Some usability issues were also found during the evaluation. We discuss how the mobile app aligns with four pillars of learning: active involvement, engagement, meaningfulness, and social interaction. Future directions on how to improve and extend our app are provided.

38.1 Introduction

During interactive book reading or sharing, children engage in conversations with their family [1, 2], which is an effective method for promoting vocabulary, language, and literacy [3–6] in children. When interactive reading is used by trained caregivers, they encourage children to participate in the conversation about the book story [7, 8]. In Costa Rica, book sharing is rare among low-income families [9], partly because

J. A. Mejías · A. M. Carmiol
Instituto de Investigaciones Psicológicas, Universidad de Costa Rica, San José, Costa Rica
e-mail: jose.mejiasrojas@ucr.ac.cr

A. M. Carmiol
e-mail: ana.carmiol@ucr.ac.cr

J. A. Mejías · C. Quesada-López · A. Martínez (✉)
Escuela de Ciencias de la Computación e Informática, Universidad de Costa Rica, San José, Costa Rica
e-mail: alexandra.martinez@ucr.ac.cr

C. Quesada-López
e-mail: cristian.quesadalopez@ucr.ac.cr

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access to children's literature is very limited [10]. At the state level, the reading promotion policy and the policy toward early childhood favored the development of language in children under 6 years through book sharing in the family [11, 12]. Such policies reflect a national interest in promoting interactive reading, but their implementation is still limited, especially for children under the age of three.

This gave rise to the idea of a technological services platform for promoting interactive reading. The research reported herein entails the design of a mobile application that supports interactive reading between caregivers and children aged 15–24 months. The high coverage of mobile technology in Costa Rica [13] provides a fertile ground for the development of apps that democratize access to educational resources.

The paper is organized as follows. Section II presents background and related work on interactive reading, learning, and HCI techniques used. Section III explains the design, solution architecture, and development process as well as the main features of the mobile application. Section IV describes the evaluation process and insights from its results. Section V states our conclusions and future work.

38.2 Background and Related Work

In this section, we provide background on the interactive reading method, learning, the human–computer interaction (HCI) techniques used, and similar apps.

38.2.1 Interactive Reading

Interactive reading (also known as "dialogic reading") of children's books is one of the most effective methods for promoting language development in children [14–16]. Children who experience interactive reading have been observed to attain higher vocabulary gains than children exposed to traditional storybook reading as passive listeners [17]. The overall goal of interactive reading is for the child to become familiar with the vocabulary and the story plot of the book over multiple readings [17].

When jointly reviewing the contents of a book, the caregiver uses child-directed speech which is diverse and sophisticated, teaching the infant words that are not normally used in everyday context (e.g., giraffe, elephant, igloo, tractor) [18]. Moreover, these interactions occur in the context of joint attention, where the caregiver identifies the infant's focus of attention and refers to it, thus producing contingent speech [19].

During interactive reading, caregivers generate extra-textual comments and questions targeting the child. They include open-ended questions about the book, as well as repetitions and expansions upon the child's responses. Caregivers are also expected to follow the child's lead during the exchange by following the child's selection of a specific book or by spending more time on a specific book section based on the

child's interest. They are also instructed to connect the story in the book to the child's life [17].

38.2.2 Learning and Children Apps

Hirsh-Pasek et al. [20] created a guideline for evaluating the educational impact and effectiveness of children's apps, based on four pillars of learning: active involvement, engagement, meaningfulness, and social interaction.

An active learning environment provides activities that engage children in a continuous process of building understanding as a result of their experiences. Active learning favors vocabulary learning and boosts academic and social outcomes for children. In the context of apps, it can be encouraged by giving children control, depending on their age, so they can proceed at their own pace and interest [20].

Engagement refers to the ability of staying on task and not being distracted. Focused engagement is important for learning in early childhood. Preschoolers are particularly susceptible to distraction, as they are not yet able to inhibit attention to other stimuli. This is why educational apps should avoid potential distractions such as animations, sound effects, and tangential games that might be appealing to the child but do not aid the learning goal [20]. Hence, interfaces that support children's engagement with the learning content should be simple. In addition, parents should have a way to turn off distracting elements (tailored to child's age and maturity).

Meaningful learning includes learning with a purpose, learning material that is personally relevant, and binding new knowledge to preexisting one. Meaningful learning depends on context: familiar contexts are more effective. Learning meaningful information motivates children to stay engaged and on task [20].

Social interaction and contingency are crucial for learning [19]. Interactions like asking children questions while reading a storybook, prompting them to imitate sounds, or pointing out objects, are important for learning. Children may even develop parasocial relationships with on-screen characters if their interactions are meaningful [20].

38.2.3 Similar Apps

The three most relevant apps on the market that we researched were Háblame Bebé, Kinedu, and Dr. Seuss digital book apps. Háblame Bebé is a mobile app whose goal is to aid in the bilingual language development of children with Hispanic parents [21]. It has two main features: word counting in English and Spanish, and reading statistics. This app is intended for adult users. Similarly, Kinedu is a mobile app meant to be used by the parents as a guide for baby's early stimulation. Children do not interact directly with the app [22]. On the other hand, Dr. Seuss digital book apps are the interactive digital version of the well-known Dr. Seuss story books. These

apps stand out for their high level of interaction, as they are designed for children. However, they have an age rating of 4 + , thus excluding younger children [23]. None of these apps offer a complete solution for interactive reading. Moreover, availability of apps in Spanish was limited.

38.2.4 HCI Techniques

In this work, we used HCI techniques like contextual design, think-aloud, and user experience questionnaire. We next describe each of them.

Contextual design is a user-centered approach to design software systems and products [24, 25]. The process of contextual design helps the design team understand how the users work, in order to create software systems that support them [26]. It uses different models to materialize the gathered data: sequence, flow, cultural, physical, and artifact models. Then, storyboards and low-fidelity prototypes are created. Stakeholders give feedback on those prototypes to improve the system design [27].

Thinking aloud is a method where users are asked to verbalize their thoughts while performing certain predefined tasks. While the user is performing the tasks, she is reminded to express her thoughts, so that the collected data is more precise and rich [27]. Overall, the method consists in collecting the (verbalized) user's thoughts and then analyzing them to evaluate and/or improve the system design. The aim is to obtain information on the cognitive process of users while interacting with the system. It can be used to evaluate the usability of a system as it can reveal usability issues that hinder the user from task completion [28, 29].

A common tool for evaluating the user experience (i.e., a person's perceptions as a result of using a product) is the user experience questionnaire (UEQ) [30, 31], which is available at https://www.ueq-online.org. It considers both classical usability and user experience aspects [30, 32]. The UEQ contains six categories (attractiveness, perspicuity, efficiency, dependability, stimulation, and novelty) measured across 26 items using a 7-point Likert scale [32].

These techniques have been previously used for the design and evaluation of other applications in Costa Rica, showing their usefulness in this specific context [25, 33].

38.3 The Mobile Application Prototype

We describe here the design and development processes, as well as the solution architecture and main features of the mobile app prototype.

38.3.1 Design Process

Our design process was guided by contextual design [24]. We built several models to elucidate the users' needs. We worked on a sequence model to understand the steps involved in accomplishing the main tasks. We also created a flow model that captures interaction among caregivers and children. Finally, the main artifact identified was an Android mobile phone with limited bandwidth and small resolution, given the low-income context of our target population. Next, we analyzed similar apps in the market by identifying their main features. The main findings of this analysis were summarized and presented to the stakeholders in order to gather feedback on what features were relevant to consider in our app. Once the user's context was clear, we materialized a caregiver into a Persona: Gilda was a 48-years old caregiver with modest technological skills. Later, we created storyboards to conceptualize the new task flows. Finally, we made wireframes that went through various iterations. All design artifacts were continuously validated with our stakeholders. Once the final wireframes were approved, we moved on to the development phase, addressing technical aspects such as architecture and implementation technologies.

38.3.2 The Solution Architecture

Our solution architecture is composed of a mobile app, a backend database, and a web dashboard, as shown in Fig. 38.1. The *mobile app* is the main component, meant to be used mostly by caregivers but controllable by children as well. Its main features were implemented in a functional prototype with Flutter [34]. The *backend* is a NoSQL repository that stores children' stories, tips, and users' information. It also provides authentication service. It was implemented in Firebase given its easy integration with Flutter. The *web dashboard* serves as content manager and also allows domain experts (users of this application) to visualize metrics generated from the mobile app usage. This component was not designed nor implemented due to time constraints.

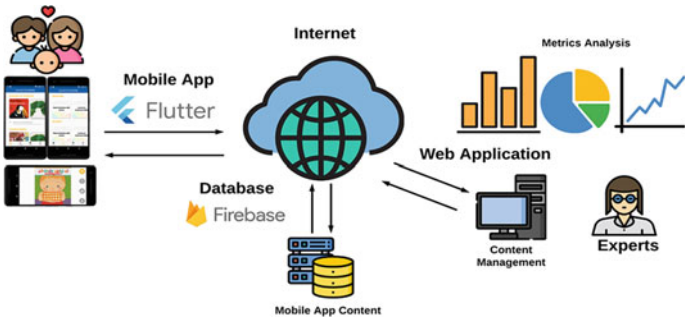

Fig. 38.1 Architecture of the solution

38.3.3 Development Process

The development process consisted of two-week agile iterations, with periodic validations from stakeholders. Only the mobile app (for Android) and backend components were developed. We chose reusable UI components and a severless option (Firebase) to reduce the development time. Only email-based registration and sign in were implemented in the authentication service. The database service was implemented with the Firebase Realtime Database [35], which stores data as JSON.

38.3.4 Main Features of the Mobile App Prototype

Our prototype mobile application has three main features. The first one is storytelling. This feature includes searching for stories and reading stories. The left-most image in Fig. 38.2 shows the Home screen where users can search for stories organized in categories. The second image is the Storytelling screen, where users can read one page at a time, with the option to turn on and off tips, narration, and background music by using the buttons at the bottom of the screen (turned on options are yellow whereas turned off options are gray). To scroll through the story pages, users must swipe horizontally. The storytelling interface is very simple, following both HCI and educational design principles.

The second feature is browsing for tips, which aims to enrich the caregivers experience with interactive reading. Tips can be text-only, image, or video, and are accessed by tapping on them. Tips shown are organized in various semantic categories. Tips can also be activated during storytelling, and some tips are included

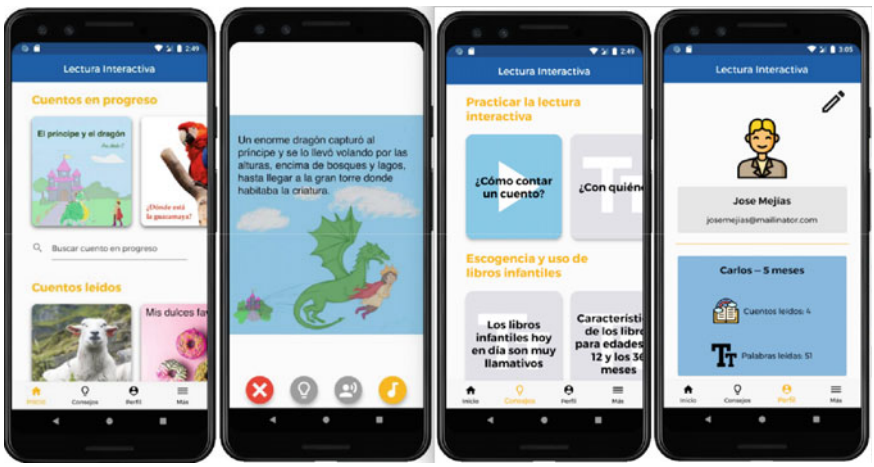

Fig. 38.2 Home, storytelling, tips, and profile screens of the mobile app prototype

at the end of the registration process. The third image from Fig. 38.2 shows the tip-browsing screen.

The third feature is user profile, which includes the registration, profile editing, and statistics. Registration collects basic data about the caregiver and children and provides information about interactive reading. Users can edit their profile information, and can also see statistics about the stories they have read with their children, including the number of words per story, the number of times a story has been read, and the time spent reading each story. The fourth image in Fig. 38.2 shows the profile editing screen.

38.4 Evaluation

Before undergoing formal evaluation, we piloted the app prototype with four volunteers who provided useful feedback and found bugs. The development team fixed these issues, generating an improved version of the app for the formal evaluation. The formal evaluation included six experts in interactive reading from three countries, who were university researchers in the fields of education, psychology, or psycholinguistics. Our goal was to evaluate the usability and functionalities of the app, and also to get expert recommendations on how the app could be improved.

Due to the COVID-19 pandemic, we resorted to virtual sessions with remote participation. We created an evaluation protocol that was used in all sessions. The development team and one expert attended each session. Zoom was chosen as the videoconference tool for the virtual sessions, since it allowed remote control of the screen. This enabled the experts to remotely control our mobile application running on an Android emulator. For experts who were unfamiliar with Android, a brief explanation was given beforehand. The actual evaluation consisted in asking each expert to perform ten tasks covering the main app features, using the thinking-aloud technique. For each task, we recorded whether the expert was able to complete it, and whether she thought she had completed it. We also noted relevant comments made by the expert, such as difficulties she was encountering or positive aspects she pointed out. Once the expert had finished the tasks, we offered a space for open feedback from the expert. At the end of the session, we asked the expert to fill out the user experience questionnaire. The session was recorded with prior permission from the expert, for analysis purposes.

38.4.1 Results of the Evaluation

The age of participants (domain experts) ranged from 37 to 57, with a median of 45 years. Half of them were Android users and half were iOS users. One of them reported having very limited experience with mobile apps. The evaluation revealed

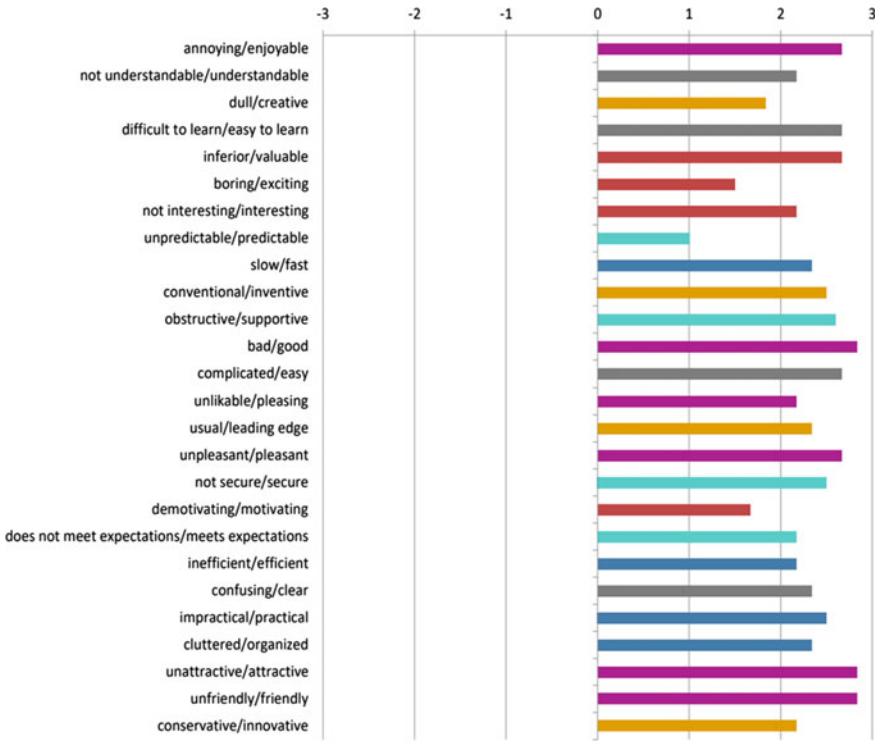

Fig. 38.3 UEQ results: mean value shown per item evaluated

two usability problems related to the profile feature, and one issue related to storytelling. Problems due to the virtual nature of the evaluation were also exposed. From the 10 tasks of the evaluation, eight were completed by all the participants without any help, and two were completed after providing some help (related to the usability problems mentioned before).

The results of the user experience questionnaire were analyzed using the procedure and tool recommended in [32]. Our results are shown in Fig. 38.3. Overall, participants had a good impression of the mobile app. In addition, Fig. 38.4 groups these results in three categories: pragmatic quality (perspicuity, efficiency, dependability), hedonic quality (stimulation, novelty), and attractiveness. Positive values were obtained in each category, meaning that the app offers a good user experience.

38.4.2 Discussion

Here we discuss how the mobile app prototype meets the four pillars of learning: active involvement, engagement, meaningfulness, and social interaction.

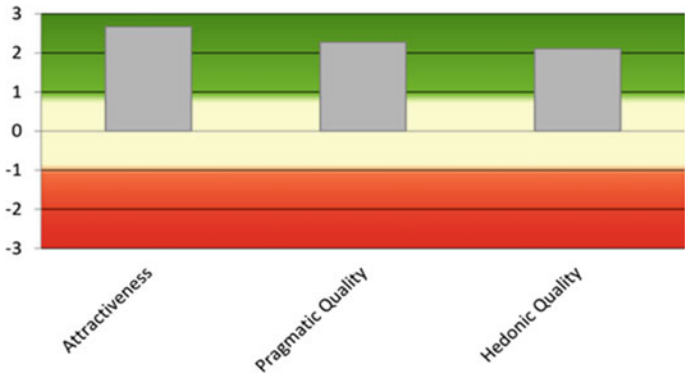

Fig. 38.4 Mean of the three pragmatic and hedonic quality aspects

Our app supports active involvement of children in two ways. First, during storytelling children can easily control the pace of the story by turning the pages themselves with a simple finger swipe. Secondly, children have at their fingertips the options to turn on or off the narrator and background music during storytelling, allowing them to customize the way the story is told, according to their preference and mood.

Regarding children's engagement, the app also supports it from its conception, as we intended the storytelling flow to be as natural and simple as possible for children and caregivers alike. In this context, a simple storytelling flow helps children stay on task. We purposely avoided games and animations, given the young age of our target children population. Also, just before starting a story, the app asks the caregiver which options to activate, configuring it in a way that is not distracting to the child.

The meaningful criterion has two dimensions to analyze: meaningful for the caregivers and for the children. For caregivers, the app offers meaningful information on how to do interactive reading effectively, why it is important and how it influences children's language development. For children, the app can be meaningful depending on the content and type of the stories. Stories should be diverse to accommodate the varied interests of all children.

Lastly, social interaction is what our application ultimately seeks, but it largely depends on how well the caregivers master the interactive reading method. Our app contributes by educating caregivers on how to effectively conduct interactive reading. The entire application is really designed for interaction, from the registration where information about the caregiver and the children is requested to storytelling where the caregiver is prompted to choose which children will participate in the reading.

38.5 Conclusions

Interactive book reading between caregivers and children, from which contingent speech emerges, has been shown to promote vocabulary gains and language development in children. Nevertheless, acquiring children's books is expensive and therefore uncommon in low-income families. To address this problem, we propose a mobile application that aids caregivers in performing interactive reading while also serving as a repository of children's books for storytelling. We presented the design, development, and evaluation of our mobile application prototype. We illustrated salient products from the application contextual design and described how other HCI techniques like think-aloud and UEQ were used in the evaluation. We discussed how our application prototype aligns with active, engaging, meaningful, and social interactive learning, rendering it an impactful educational app.

A group of six experts in interactive reading participated in the evaluation of our app prototype. Results were very positive, both from the user experience questionnaire and unstructured feedback given by the experts. Usability issues were also discovered. Overall, the app was deemed easy to use and effective in supporting interactive reading.

Future directions in which the mobile application can be improved or extended are: (1) categorizing children's storybooks by age, (2) having tips categorized by book type, (3) removing tips from storytelling and instead having a short introduction on how to read a specific book with the child, (4) if the target age range of the app is extended, older children could be allowed to choose among story characters or objects that further the storyline, to keep them engaged, (5) likewise, on-screen characters could be developed to interact with older children, leveraging the benefits of parasocial relationships.

In conclusion, we believe that apps like this should be developed and made available especially to low-income families, in trying to close the existing education gap. Apps for interactive reading should target both caregivers and children, as caregivers would benefit from preparation and training on interactive reading, and children would learn better if they are given some control over what is read and its pace. In addition, apps with an educational goal like this one should take into considerations the pillars of learning from its inception.

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