Bilingual Storybook App Designed for Deaf Children Based on Research Principles

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Abstract— *The Baobab* is the first bilingual storybook app for touchscreen tablets that was designed and developed based on research in visual learning, visual phonology, bilingualism, and deaf children's cognitive development by the National Science Foundation-funded Science of Learning Center on Visual Language and Visual Learning (VL2) at Gallaudet University. Developed by an all-deaf team, this VL2 storybook app is designed for early and emerging readers, bridging design principles in ASL storytelling and English text to research foundations, in order to facilitate reading and language acquisition for children who rely on the visual modality for learning.

1. Motivation

Nearly 96% of the deaf children are born in a family whose parents are not deaf (Mitchell & Karchmer, 2002.) Language acquisition and development are of a concern among those deaf children whose parents do not sign at an early age. Early language exposure is crucial to children's ability to become lifelong learners (Mayberry, 2010; Mayberry, 2007; Mayberry, et al., 2002).

Released in February 2013, and available on the Apple App Store, *The Baobab* is the first interactive and bilingual (American Sign Language and English) storybook app for the iPad designed to facilitate language acquisition and reading for all young children, especially deaf and hard of hearing children who are emerging and early readers (ages four and up). With interplay between a real life person using American Sign Language (ASL) and animations with vivid watercolor illustrations, this app showcases professional ASL storytelling in full story mode. The main feature is the design of the reading part of the app, which features

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page-by-page ASL videos to accompany the story text in sentences. In the read mode, there are highlighted vocabulary words linked to ASL videos, which brings children from the printed English word to the signed version in ASL, which also includes fingerspelling. *The Baobab* has a glossary of 170 vocabulary words, in English text, ASL, and audio voice-over in English. This app is custom designed with a framework intended for future productions of more bilingual storybook apps by replacing story assets (videos, images and text). At the time of writing, four more storybook apps are in development.

The significance of using touchscreen tablets for bilingual and bimodal immersion comes from the fact that videos and text can be seamlessly integrated on the same screen. Although there are bilingual stories on DVD with the text appearing next to the signers along with illustrations., the reading and viewing pacing on DVDs are automatically set, unless someone pauses, rewinds, or goes forward in the story. This approach to bilingual learning was challenging because children had little or no control over the pace, and they had to divide and alternate their attention between the signer and the text on the screen. Moreover, children had to read the book before or after viewing the ASL version of the text on the screen. With the emergence of touchscreen tablets, engagement in visual language and printed text (literacy) became possible. By integrating videos and text seamlessly on the same screen, children can move through the story at his or her own pace without any assistance from adults, which has been demonstrated to significantly impact learning (Balci, 2009).

2. Research-Based Design

The key design features include the promotion of vocabulary learning and comprehension within context of the whole story with support of video, fingerspelling, and brilliant illustrations. The research-based approach regarding to VL2's center findings, exposure to both languages and use of Top-Down Theories (Goodman, 1986; Rayner, et al., 2002) and Whole Language Approach (Heymsfeld, 1989) were used to support bilingual development.

The incorporated components in the design of the app are built using an evidence-based approach to increase motivation for children to read. The design foundations and core approach in development are directed by three top research discoveries made in the learning labs of the

Science of Learning Center on Visual Language and Visual Learning (VL2). First, the early visual language experience has been shown to impact children's visual gaze-shifting and visual attention in the young deaf learners, which in turn enhances book-sharing and literacy behaviors in toddlers and offers other far-reaching benefits for a deaf child's linguistic, communicative, cognitive, academic, literacy, and socio-emotional development (Visual Language and Visual Learning Science of Learning Center, January 2011; June 2012). Second, the age of first language and first bilingual (ASL and English) language exposure has a powerful impact on the deaf and hard of hearing child's ability to develop complex reading knowledge (Jasinska & Petitto, 2013; Berens, et al., 2013; Petitto, et al., 2012). Third, visual sign phonology, especially fingerspelling, positively impacts learning to read in young deaf and hard of hearing children (Visual Language and Visual Learning Science of Learning Center, June 2011).

The delivery of a rich ASL and English model in this app is expected to enrich vocabulary development in both languages. With this app, a child (or parent) will have the opportunity to enjoy a story and see the vocabulary words in English print, hear the word in English, and see the storyteller signing and fingerspelling the word. Educators may use this app as a resource in their instructions when promoting metalinguistic awareness. Our ASL story includes many complex linguistic structures, ranging from role shifting to locative and depicting classifiers. To bridge both languages, ASL and English, young and emerging readers need to comprehend the grammatical structures in ASL, and to build metalinguistic awareness before learning the same concept in English language (Cummins, 2001),.

The reading design of this app is based on Top-Down and Whole Language Approach. The Whole Language reading instructions by first comprehending the whole and then interpreting parts of the whole are guided by Top-down theories. Children can watch the whole ASL translation in "watch" mode and view illustrations in "read" mode of the app. Next, children can view the ASL translation of each page with English text in the "Read" section of the app and read English text independently or with teacher/peer support. They can tap on the "active" (hyper-linked) vocabulary words for additional support with comprehension (see figure 1). The child has an array of options, from reading and re-reading the English text, to watching and re-watching the ASL story, with or without a peer.

Grimshaw, et al., (2007), found that comprehension scores of children listening to narration were significantly higher than the children who read the story only. We would expect a similar result; that is, children who view narrative stories in ASL would likely be able to answer comprehension questions with greater accuracy than those who only read the English story text, absent the ASL narration. Research has shown an increase in motivation among children in reading if they are able to listen to the stories being read out aloud. The same principle goes for supplying definitions during reading (or, in the case of this app, in form of signed/fingerspelled/voiced word) for selected vocabulary words (Herzig, 2009).

For reading fluency and high-level comprehension processes to take place, lower level processes such as rapid word recognition need to occur which aids reading fluency (Torgesen & Hudson, 2006). As the vocabulary knowledge base accrues, or leveraging knowledge from ASL to English, the child can benefit from top-down reading processes. Research studies on fingerspelling conducted by Baker (Visual Language and Visual Learning Science of Learning Center, 2010) and Padden (1996) emphasizes the importance of fingerspelling for reading. The studies suggest that early fingerspelling exposure helps deaf children become better readers, fingerspelling and literacy development are interrelated, and it facilitates vocabulary growth. Chaining techniques, in which the signer signs the word, fingerspells it and then signs it again, are used in this storybook app and is an effective literacy strategy for deaf learners (Padden & Ramsey, 2000). Further vocabulary and spelling practice with sign and fingerspelling are offered at the end of the storybook glossary in the "Learn" section. In general, children using e-books use the online dictionary feature significantly more than a printed dictionary related to the same books (Grimshaw, et al., 2007). The glossary tool in this storybook app will be useful for promoting the vocabulary development among children.

In sum, the use of a VL2 bilingual storybook app supports deaf children's bilingual language development because:

- Children can see printed English text
- Children have access to a fluent ASL model
- The illustrations provides semantics and visual clues
- Children get exposure to fingerspelling
- Children experience agency by interacting with the interface
- Touchscreen tablets promote visual engagement and literacy enjoyment

3. Development

The introduction of touchscreen tablets has revolutionized the ability to integrate scientific findings and design aesthetics to create a seamless user experience, especially for deaf children. Videos and text are integrated on a single interface, which opened up much potential for sign language in the design and development process.

A. Supported Platform

This app was built to run on an iOS framework. This app runs on all versions of iPad and iPad Mini, with optimized images for retina displays. Android versions are currently in development with an identical framework.

We encountered issues related to the size of the app in memory capacity with the heavy video-integrated design. Future productions will focus on reducing app size. Current app size is 850 MB.

One of the main goals of the app design is to keep the experience as intuitive as possible, which led us to develop two possible ways to view the vocabulary videos. Users would have to touch/or tap on the highlighted word to open a "pop-up" video to show the sign and fingerspelling of the particular word. Users can go ahead and tap anywhere on the screen while the video is playing; doing so will cause the video to close. The other way is to touch and hold on the selected text.

B. Content Development

The storyline of *The Baobab* was created, first in ASL, with the whole narrative visualized, mapped out, and recorded on film at Motion Lab, Gallaudet University. The narrative was then transferred to a storyboard, where we started to identify page by page, structuring the sentences. The ASL narrative changed several times (influenced by children-based focus groups). When the final version was determined, we used the storyboard to help structure the translation into English.

With the content in English set, the next stage was identifying which vocabulary word would have a video, thus becoming "active." In production, the storyteller would include regional variations of the signed words, which required screening post-production to select the ones that matched the story context. For instance, the word "TRUNK" has two meanings, as in an elephant trunk or in a tree trunk. There are also two different signs for the same word. Our approach is to provide different signs of words, in accordance to story context, which means the word "trunk" appears twice in the glossary ("Learn" section) of the app, but shown in different signs. There are 170 vocabulary words in the "Learn" mode in *The Baobab*.

Fig. 1 Read mode: Highlighted vocabulary videos

To support story comprehension through artwork, a deaf artist was commissioned to do the illustrations for the story, which was done by hand in watercolor.

C. Not a "read-along" storybook app

This is not a regular "read-along" book where text is supported by a voice-over, but rather the design of this app is influenced by the grammatical structure and nature of two languages. In this design, only the vocabulary words have voice-over. Audio in all vocabulary words appears as word for word and letter for letter. (For instance, "Tree" will appear as "Tree, T-R-E-E, Tree") which also appears in the "Learn" mode.

The "Watch" mode comes with an animated background to heighten understanding of the story itself, and to engage young readers. In the "Read" mode, both languages can be presented on the same screen if users tap on the play button, which opens up the sentence video. Children can alternate their gaze from the video in ASL to the text below, or choose to focus on the video. It is because of the array of choices, we refrained from adding animation in the sentence video. This also influenced our decision not to add audio to the sentence videos, as the text is already presented. In addition to the busy interface in "Read" mode, grammatical structure of ASL and English is different that an audio voice-over would not be in the same order as ASL.

The Baobab app is designed to support two languages with different grammatical structures, and the goal is to encourage ASL development and reading fluency for children. The intention of having no voice over for ASL version in "Watch" mode or for sentences in "Read" mode, is to encourage the child to be fully immersed in one language.

D. Focus Groups

During development and production, there were two focus groups. The first focus group on the ASL presentation and the context of the narrative. It was assessed whether the story is comprehensible enough for students in that age range (3-7 years old), and if the story is of high-interest level. With the second focus group, the user experience were tested.

The narratives were shown in video to students in preschool, pre-kindergarten, kindergarten, and first grade at two different schools for the deaf. One school was in Washington, DC, and the other was in Fremont, California.

For the evaluation of the user experience in a natural setting, 12 deaf children (ages 3 to 8 years old) interacted with the beta version of *The Baobab* in their homes.

Through the evaluations of user experience, revisions were made to the design, in particular, how vocabulary words were highlighted. The color was changed, which resulted in different engagement, with children becoming more responsive to the active vocabulary words, tapping to activate the videos.

4. Legal Obligations

To ensure that we protected the public from this product, which have not been peer-reviewed or evaluated, this product was shared with the Benefits and Risk Assessment Committee at Gallaudet University. Benefits and Risks

Assessment Committee was founded by VL2 at Gallaudet University and is the first of its kind in the nation. For the committee, the developer of this app presented the Theory of Action (reason for developing this product), Theory of Change (what impact we hoped this product would have on visual learners), and Risks (that may be involved and our plans to minimize them.) Potential risks involve marketing a product whose efficacy had not been fully demonstrated, being wrong or misunderstood in the manner with we interpret research findings in the design of the product, and causing undue financial expenses for product purchasers who may have unrealistic expectations regarding the benefits of the product. The committee, then, evaluated the product and determined the benefits outweighed the risks and approved the release of this product.

5. Evaluation

With the release of *The Baobab*, we implemented data tracking using Localytics (a platform designed for "e-books" tracking) to track the user experience. All data is anonymous, but we are able to see which vocabulary word has been tapped on, and on which page, and for how long. Users have the option of "opting out" of data tracking through settings. Based on the data collected through Localytics, we will determine user characteristics.

Our current studies include tracking the eye-gaze behavior of users through Tobii Eye-Tracking equipment, outfitted for mobile devices. We aim to learn if differences in visual language and sensory experiences impact how the human brain processes language. Specifically, the question is will a deaf child's visual attention systems, which are central to language and reading development, be altered by early visual language exposure? The *hypothesis* that differences in visual language experience (early vs. late) alter the brain's developing visual attention systems and their upstream role in emergent literacy will be tested.

In this case, early-exposed and later-exposed deaf children will show differences in allocation of visual attention to components of the linguistic signal and non-linguistic content. Such a finding would reveal the importance of early visual language experiences in promoting deaf children's language and literacy development.

After evaluating the user characteristics and user experiences, we plan to execute efficacy studies, which includes student and teachers uptake of the app at school and with families. The results will help guide our design for subsequent apps and to help create guidelines and lesson plans for teachers and parents.

6. Links

The introduction of touchscreen tablets has revolutionized the ability to integrate scientific findings and design aesthetics to create a seamless user experience, especially for deaf children. Videos and text are integrated on a single interface, which opened up much potential for sign language in the design and development process.

To download *The Baobab*, please go here: http://bit.ly/15XN7ev (iTunes App Store). Official websites: www.vl2storybookapps.com and http://vl2.gallaudet.edu.

Acknowledgment

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