Bilingual SpeechBlocks: Investigating How Bilingual Children Tinker with Words in English and Spanish

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ABSTRACT
Many children in the United States speak a language other than English in the home, yet the literacy learning mobile apps and games available do not reflect the country's growing number of bilingual children. Furthermore, to the authors' knowledge, none of these apps provide open-ended, constructionist literacy learning opportunities for young bilinguals. In response, we created Bilingual SpeechBlocks, a version of the constructionist literacy learning app SpeechBlocks, for young children who speak both Spanish and English. We discuss the design considerations and examine the affordances of this app when tested with bilingual children, in comparison to the original monolingual app. From our observations, this version of the app enables new modes of wordplay and engagement for bilingual children and their families. This work has implications for how open-ended designs can foster bilingual literacy learning by encouraging language differentiation through exploration and providing natural opportunities for family co-engagement.

ACM Classification Keywords
H.5.m Information interfaces and presentation (e.g. HCI): Miscellaneous

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Bilingualism; mobile app and game design for children; constructionism; early literacy learning

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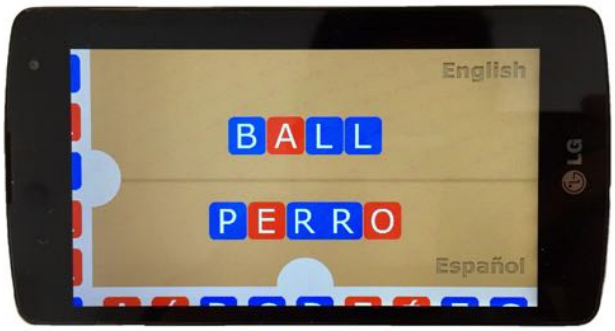

Figure 1: The main screen of the Bilingual SpeechBlocks app (BSB).

INTRODUCTION
As 22% of school-aged children in the United States speak a language other than English at home and the number of bilingual speakers is predicted to continue growing [36], bilingualism is an increasingly important focus in the U.S. educational system, especially when it comes to learning to read and write. Additionally, as educational technology, such as learning apps for mobile devices, becomes more prevalent in homes throughout the world, it is extremely important to develop high quality educational content for these technologies that are child-interest driven and contextually relevant [43]. Yet despite these trends, there are very few high quality early learning apps that are being developed for bilingual children and their families [20]. In response to this disconnect, we created Bilingual SpeechBlocks (BSB) (Figure 1), a constructionist literacy app that provides an open-ended canvas for children to explore the phonetic rules of both Spanish and

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English. BSB is a variation of the original SpeechBlocks app, which we will refer to as monolingual SpeechBlocks (MSB). MSB is a self-expressive literacy app that specifically focuses on helping children explore the phonetic rules of English [39]. In this paper, we will use the word app to refer to a game designed for a mobile device.

Our Motivation and Purpose

The creation of BSB was inspired by Pearson et al.'s research [29, 28]. They found that when bilingual children were given an assessment in one language, their rate of vocabulary learning was half that of monolingual children, but when they were given an assessment in both of their languages, their rate of vocabulary was equivalent to monolingual children's. Thus, it is important to consider the languages a child is exposed to when designing literacy learning experiences because bilingual children's language and literacy abilities are distributed among two languages [18, 21, 33]. This research made us question whether MSB was unintentionally impeding upon bilingual children's word play simply through providing a solely monolingual experience.

The particular design of BSB was further motivated by research on how bilingual children learn to read and write, especially for languages with similar orthographies such as Spanish and English [10, 38]. This research suggests that it is important for children to distinguish between the phonetic rules of the different languages they speak [10, 8, 38, 24].

In light of this research, we see an opportunity for educational apps and games to help bilingual children improve both their Spanish and English language abilities. Thus, we decided to create BSB so that Spanish and English-speaking bilingual children can explore the alphabetic principles of their two languages side by side. Rather than create a tool for translation, we opted to create a tool that could facilitate differentiation between the orthographies of English and Spanish, an important milestone for bilingual children [13]. The purpose of this paper is to examine how incorporating two languages into the design of SpeechBlocks may change bilingual children's nature of word play and engagement within the app. We do this by presenting the design decisions of BSB and sharing some observations from our exploratory pilot study with the app.

BACKGROUND

Bilingualism and Learning

Bilingualism is an important issue in the United States educational system, as growing up bilingual in an English-speaking school system has both advantages and disadvantages in terms of learning. According to a report by the U.S. Department of Education [31], the number of school-age children in the United States who speak a language other than English in the home grew dramatically from 9% to 20% between 1979 and 2007. Of those children, 75% spoke Spanish in the home and spoke English with difficulty. On average, it takes two to three years for these children to reach their monolingual peers' conversational abilities and five to seven years for them to be on par with their monolingual peers in academic performance [7]. However, this may differ depending on their exposure to English before entering school. Hammer et al. [15] demonstrated that children who were exposed to both Spanish and English at home had stronger English abilities upon entering Head Start (a nationwide early childhood education program in the United States), while children who were exposed to and communicated in only Spanish before entering Head Start had stronger Spanish abilities.

English-Spanish bilingualism has many advantages. Fluency in both languages can help with better semantic, phonological, and grammatical awareness [3, 4, 5, 6], as well as enhanced creativity and stronger academic performance [14]. It can also help support children's psychological development and social development (i.e. identifying with others in their communities) [26]. Therefore, the research suggests that bilingual education has many developmental and academic advantages for children who are exposed to both languages at an early age.

Despite all of the academic advantages of bilingualism, there are also many challenges that bilingual children face while learning to read and write in their two languages. When bilingual children are reading a word in one language, researchers have observed that they activate their lexical knowledge in both of their languages [37]. In particular, Spanish and English have partially overlapping orthographies [37]. Thus, negative transfer between the two languages tends to occur during spelling or word recognition tasks for bilingual Spanish-English speaking children [10, 8]. The problem which occurs is that, despite their overlapping orthographies, Spanish and English follow different spelling-sound correspondences. Durgunoğlu [10] explains that, when trying to spell a word in English, children may systematically use the sounding out strategy, which is effective in Spanish, but is much less effective for English, which has a less-transparent orthography. In contrast, children may also use common English consonant clusters when spelling in Spanish (e.g. scuela for *escuela*, stoy for *estoy*, different for *diferent*) and interchange sounds between English and Spanish, such as confusing the letters "i" and "y" (e.g. spelling happily as "hapali") [10]. Research by Simpson [38] shows similar findings for bilingual Spanish-English first graders, who tend to make errors in their English writings by using Spanish phonetic rules for invented spellings of English words (e.g. spelling bee as "vi" and tree as "tri").

Due to this negative transfer of knowledge between languages, literacy teachers may worry about bilingual students confusing their two languages [10]. In response, research by Ortiz [25] and Cummins [8] both stress the crucial role that teachers play in not only understanding the benefits and limitations of cross-linguistic transfer, but also in explicitly teaching strategies to help children differentiate between writing in Spanish and English [24]. Therefore, it is important for bilingual children to understand how to differentiate between the phonetic rules of each language as they develop their reading and writing skills.

Family Co-Engagement in Literacy Learning

Acquiring oral language can be described as a "social dance" between parents and children [16]. The next step, developing literacy skills, is ideally also a collaborative learning experience facilitated by a feedback loop between the child and the

parent, where both are learning how to communicate with the other. Digital technology has the potential to support family co-engagement in literacy learning activities. However, most digital literacy tools fail to include this collaborative experience. In fact, in a recent survey of popular children's literacy learning apps, researchers found that for every literacy app that promotes a collaborative experience, there are 85 that do not [43].

Many parents are eager to be part of their children's learning experience as both collaborators and role-models [32, 30]. Additionally, studies have found that children's comprehension improves when parents engage in media-rich learning experiences (e.g., watching educational television) together with their children, in part because the parents discuss and contextualize the on-screen scenarios [40]. When only one language is spoken in the home and that language is different from that of the media-rich learning experience, it makes it much harder for parents to co-engage. Bilingual learning experiences, such as bilingual literacy apps, may help to address this problem.

Constructionism and Literacy Technology

The majority of educational apps on the market prescribe to the instructionist paradigm of delivering literacy lessons, where the main mode of interaction is directed, such as dragging and dropping letters to spell a predefined word [43]. However, research suggests that these structured, rewards-based games do not always lead to the best learning outcomes for children [17]. In contrast to this, activities focused on creation help children to develop a deeper understanding [34], especially in relation to reading development. One proponent of this in the field of literacy learning is Maria Montessori, who believed that children should learn writing, the literary form of creation, before reading [23]. This idea that child-centered, creative environments facilitate deeper learning among children also lies at the core of Papert's [27] constructionist approach to learning.

The goal of constructionist, or design-based, learning environments is to create an open space which allows for learners to find projects that are personally engaging and intellectually interesting rather than instructor-directed learning activities. Resnick, Bruckman, and Martin [34] proposed two principles of design-based learning that contribute to rich learning experiences: personal connections, which increase relatedness and motivation; and epistemological connections, which encourage new ways of thinking through the iterative design process. Similarly, work by Gee [12] on educational games, suggests that significant learning occurs through doing, exploring, and creating; where experiential learning through contextualizing the material lends itself to a deeper understanding by applying knowledge to solve problems, rather than just memorizing facts. We believe this is especially pertinent for language and literacy learning, where it is important for educational technology to allow children to explore the phonetic rules of a language rather than only creating and memorizing sight words.

One such app that we believe follows the constructionist principles of exploration and creation to produce personally meaningful learning moments is MSB. MSB is an open-ended literacy app where children explore alphabetic principles through manipulating letter blocks [39]. This original version of the app is the foundation for which BSB is built upon. In MSB, children can blend and segment phonemes into real and nonsense words by dragging letter blocks apart and pulling them together [39]. There are no correct combinations of letters, no extrinsic rewards, and contingent interactions have immediate auditory feedback. Words from a "word drawer" and letters from a "letter drawer" act as scaffolds that children can use and remix [39]. However, MSB is monolingual, specifically focusing on helping children explore the phonetic rules of English.

Bilingual Literacy Learning Mobile Apps

Smartphones are increasingly ubiquitous in American homes. In the span of just two years from 2011 to 2013, the percent of children ages zero to eight years old with access to a smartphone and/or tablet has increased from 52% to 75% [22]. Though there are reasons to be concerned about too much screen time for children, parents are also beginning to see educational apps as a part of their children's learning experience. Vaala, Ly, and Levine [43] stated that Hispanic families, in particular, see strong educational potential in media, including apps, for their children's learning.

Like MSB, most of the popular educational mobile apps are focused on children's language and literacy skills in one language. In a survey of the 183 most popular educational apps on the market, only 13 apps included features and techniques to help children learn a second language [43].

Upon review of popular bilingual literacy learning apps, we could not find any apps that allowed bilingual Spanish and English speaking children to explore the alphabetic principles of their two languages side by side. However, there are a few apps that help these children develop their abilities in one of their languages, while allowing them to use their other language to provide context. For example, Endless Spanish [19], in addition to using verbal and pictographic cues in Spanish to convey a word's meaning, provides the oral translation of the word in English so that the learner can use their English understanding to provide context. Rosetta Stone Kids Lingo Word Builder [35] helps reinforce early reading skills in English while simultaneously introducing oral skills in Spanish. Montessori Letter Sounds [1] allows children to play with letter sounds in Spanish while listening to the instructions in English.

Furthermore, all of the apps mentioned above followed some version of the instructionist mode of delivering literacy lessons, providing word and/or sentence-level puzzles with defined answers that children are tasked with solving. In general, there are very few constructionist, or self-expressive early literacy learning apps available on the market [17, 43] and, to the authors' knowledge, this list dwindles to zero when searching for a constructionist bilingual literacy app. Given the literature on the importance of early exposure to multiple languages for bilingual children and the benefits of constructionist learning apps, we believe that there should be more development of constructionist bilingual literacy apps for young children and families.

DESIGN

Design Questions

We developed BSB to serve as a platform for bilingual children's open-ended Spanish and English wordplay. We will use this paper to examine the following design questions: What are the different affordances of the two designs for bilingual children and their families during play? Is the bilingual version more personally meaningful for children? And lastly, how engaged are children when using BSB versus MSB? Finally, we will discuss the implications and limitations of the design and share our plans for future research with the BSB app.

Overview of Design

As mentioned above, BSB builds off of the original SpeechBlocks app by allowing children to create words in both Spanish and English. This literacy app follows the same constructionist approach to dual-language learning by encouraging the exploration of the alphabetic principles of the two languages through manipulating letter blocks (see Figure 2). When letter blocks or combinations of these blocks are tapped, put together, or pulled apart, they are pronounced. There is a line in the middle of the screen (midline) that separates the Spanish and English halves of the canvas.

Children can create words in either half of the canvas, and then drag that word to the other half to hear how the pronunciation of the same word changes between languages. Just like regular SpeechBlocks, there is no right or wrong combination of letters (children can create both real and nonsense words), no extrinsic rewards, and contingent interactions have immediate feedback [39]. Both English and Spanish words from the "word shelf" and letters from the "letter shelf" act as scaffolds that children can use and remix.

As previously mentioned, this is not a translation tool, rather it is an open canvas where children can explore the phonetic rules of each language and differentiate between them. This design decision to focus on differentiation was informed by the research that bilingual children struggle with negative transfer between the two languages when learning to read and write [10, 8, 24]. Therefore, we created an environment where children could immediately hear the differences in pronunciation of the same orthography between the two languages and compare the sounds.

Specific Design Considerations

Segmentation of the Canvas and Dual Voices

The BSB canvas is separated into two halves: A Spanish half and an English half (Figure 2A). When a child taps on a word in the Spanish half of the canvas, a voice synthesizer reads out the word in a Latin American Spanish pronunciation; when a child taps on a word in the English half of the canvas, a voice synthesizer reads out the word in an American English pronunciation. Both voice synthesizers used were built by Ivona Software[1] and the English synthesizer was modified in the original SpeechBlocks app to handle a set of phonemic edge-cases (e.g. AC is pronounced /ac/ instead of treated as the abbreviation of "air conditioner"). The midline provides

[1] https://www.ivona.com/us/about-us/voice-portfolio/

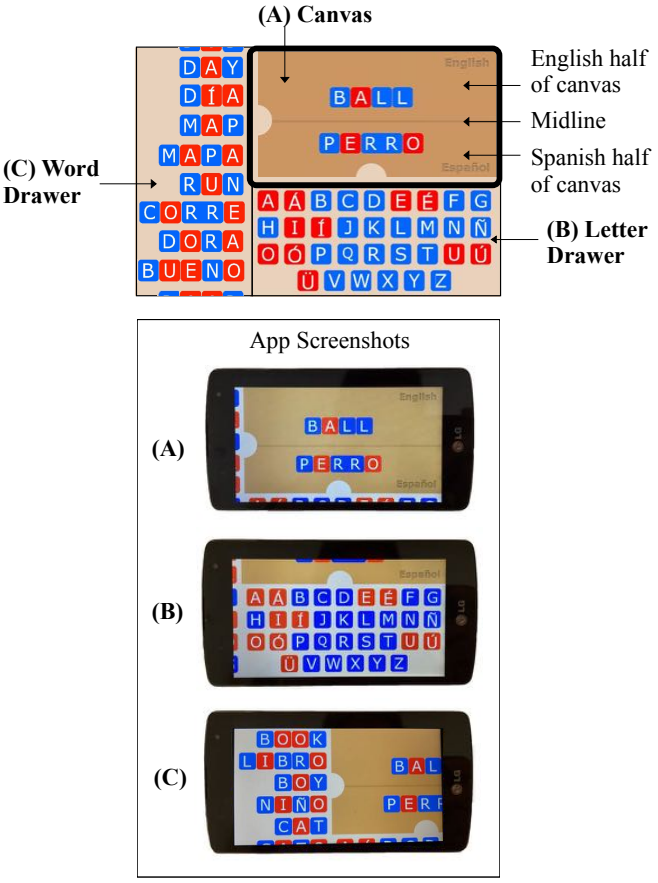

Figure 2: Diagram of the Bilingual SpeechBlocks App. **(A)** The Bilingual SpeechBlocks canvas, **(B)** the Bilingual SpeechBlocks letter drawer, and **(C)** the Bilingual SpeechBlocks word drawer.

the ability for children to toggle between both languages in the same space in order to make an immediate comparison between how a word, real or nonsense, is pronounced in the two languages. This is the most distinctive feature of BSB.

Addition of Spanish Letters

There are 33 letter-blocks in the letter drawer (see Figure 2B). Twenty-six of these blocks represent letters used in both the Spanish and English writing systems. The seven remaining blocks represent letters that are unique to Spanish. They are Ñ, Á, É, Í, Ó, Ú, and Ü. As in MSB, the letter-blocks are arranged in alphabetical order [39]. The letters with accents follow directly after the corresponding letter without an accent. Since both English and Spanish are alphabetic languages with overlapping orthographies, we decided to use only one drawer for both languages.

One design decision that was made is, when a letter in the letter drawer is tapped, only its Spanish pronunciation is read aloud. This is because we wanted to keep the pronunciation of letters in the letter drawer constant and all of the letters are pronounceable in Spanish but not in English. Additionally, Spanish has a more regular letter-to-sound mapping [37],

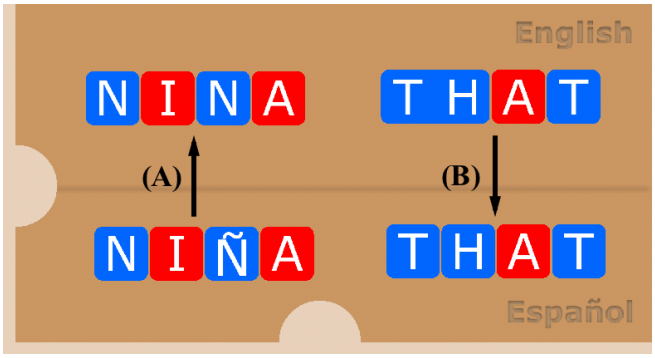

Figure 3: Letter transitions from one half of the Bilingual SpeechBlocks canvas to the other. **(A)** The "Ñ" becomes an "N" (the most similar English letter) as the word "NIÑA" is moved from the Spanish to the English half of the canvas. **(B)** The "TH" digraph splits apart into two letter-blocks as the word "THAT" moves from the English to the Spanish half of the canvas.

making it the more natural choice. We thus decided to position the letter drawer underneath the Spanish half of the BSB canvas to keep its location consistent with both the Spanish pronunciation of the letters in the drawer and the design of MSB.

While we recognize that, in Spanish, the entire word is usually written and then the accent added to one of the vowels if needed, we decided to put the letters with accents on their own letter-blocks. This was in order to (1) give the accented letters equal importance as the non-accented letters to inspire children to tinker with all of the letter-blocks and (2) to maintain the same word-construction system (i.e. side-to-side concatenation) in both languages.

Letter Transitions

Since the accented letters are only found in the Spanish writing system and not the English system, we implemented slight animations to these letter-blocks when they transition from the Spanish canvas to the English canvas across the midline. For these accented letters (Ñ, Á, É, Í, Ó, Ú, Ü), the accent is removed when the block touches the English half of the canvas, turning into the English letter most similar to it (N, A, E, I, O, U). The accent returns if the block crosses back into the Spanish half, but only if the original block had an accent when it was brought onto the canvas from the letter or word shelf (see Figure 3A).

Additionally, the letter blocks change slightly when they are used to represent digraphs. A digraph is a combination of two letters that can be represented by one sound, and that sound is different than the sounds of either of the two letters by themselves. In MSB and BSB, common digraphs are represented by the two letters appearing as one block (however, these can still be pulled apart). There are several digraphs present in BSB for Spanish (LL, RR, and CH) and English (SH, TH, PH, and CH). As these digraphs differ between Spanish and English (with the exception of CH), when a digraph crosses the language line, it appears to split into two blocks, and each letter is pronounced separately (see Figure 3B).

The slight animation in our design as a word crosses the midline allows the user to distinguish between the words or letters that have different orthographies between the two languages. As indicated by the research, Spanish and English have overlapping orthographies [37] and, therefore, we decided to let the speech synthesizers audibly pronounce the differences between the two languages for all words and letters, yet only visually animate the words and letters that change orthographies between the languages as they cross the midline.

Addition of Spanish Words

There are 45 words in the word drawer; 22 Spanish words and 23 English words (see Figure 2C). With the exception of three words related to the bilingual (Spanish-English speaking) children's character Dora the Explorer[2], all of these words were selected from the Spanish and English short forms of the MacArthur-Bates Communicative Development Inventories (CDI) [11]. The CDI forms have common words that parents can use to assess the vocabulary development of their children in the home, and the words on these forms represent vocabulary words that are frequently heard in the child's environment [6]. Since the main interaction in BSB is largely based on auditory feedback from the app, it was important to choose words that the child would have previous exposure to (e.g. water or *agua*), rather than focus on words that are typically taught in early literacy instruction, such as consonant-vowel-consonant (CVC) words (e.g. pop or bat).

There were a couple of design considerations when selecting scaffolding words. First, the words cannot exceed five letters in length due to space constraints of the word drawer. Second, words that would produce drastically different sounds in Spanish or English (e.g. ball, *niño*, *perro*) were more favorable than words with similar sounds in the two languages. Third, special attention was given to choosing words that contained the different digraphs in each language. Lastly, a majority of the selected words had to be present in both Spanish and English CDI forms so that both translations of these words could be placed next to each other on the word shelf. Since BSB is not a translation tool, this was done to make sure that the support and scaffolding provided by the word drawer was approximately equivalent for both languages.

METHODOLOGY

Initial Play-Test

Before conducting an exploratory pilot study, we play-tested BSB and MSB with two Spanish-English bilingual children (one female and one male, ages 6 and 8 years old) at an after-school tutoring program in the Greater Boston area. Each child played a version of the SpeechBlocks app (in randomized order) for approximately ten minutes while the researchers

[2] http://www.nickjr.com/dora-the-explorer/

took observational notes of engagement during play. The following week, children were given the other version of the app to play for another ten minutes. Their parents were not present in the room during the play sessions. When each child was finished, they were asked for their feedback on the two versions of the app.

There were many limitations of play-testing SpeechBlocks in this context. First, the availability of time and space at the after-school program was limited. Second, there were many distractions present in the room while children were playing with the app. Third, the amount of time children could play varied depending on how much homework they had to complete. Lastly, having multiple play sessions for each child proved problematic, as children's attention spans and interest varied across the play sessions. As a result, we revised the study procedure for our pilot study, which is outlined below.

Participants

We conducted a small exploratory pilot study (which we will refer to for the remainder of this paper as the "study") with seven bilingual children at an after-school program for families in the Greater Boston area. There were three female and four male children that participated, ranging in age from 5 to 9 years old (average age of 7 years old). Children between the ages of 5 and 9 have vastly different literacy skills. However, given that the open-ended and responsive nature of both MSB and BSB allows children to make any simple or complex words they desire, we believe that these apps are appropriate for a wide age range. All of the children in this pilot study were from low socioeconomic status neighborhoods, had parents who immigrated from Latin America, used Spanish as the primary language of communication with their parents, and were the first generation in their family to receive K-12 education in the United States. Quantitative analysis was conducted for the seven children in the pilot study. However, all nine children's play (the seven children from the pilot study and two children from the initial play-test), was used for the qualitative, observational analysis.

Pilot Study Procedure

The study session took about 30 minutes per participant, and the children worked individually with two researchers in a small teacher's lounge in their public school. For the seven children who received the standardized study procedure, their parents were given the option to be present in the room with their child and the researchers during the study. Since children have varying levels of bi-literacy, we conducted a pre-assessment of children's phonemic decoding skills for both Spanish and English nonsense words. For this pre-assessment, we adapted 24 words from the TOWRE-2 standardized assessment [42] and read them to the students in a randomized order, pronouncing each word using English and Spanish phonetic rules. The child had to determine whether the word was being pronounced in Spanish or English. This assessment allowed us to ensure that every child in the study had a baseline knowledge of differentiating between Spanish and English pronunciations. All seven children scored above the baseline cutoff of 50% on the pre-assessment for both Spanish and English (average English score was 89%, average Spanish score was 87%), and thus were included in the study.

After the pre-assessment, the child received either MSB or BSB (in a randomized order). The app was introduced by one researcher, who demonstrated the app's basic functions (using the drawers, creating words, segmenting words, and deleting words). When BSB was introduced, the researcher used the same instructions, but also explained that there was a line that the child could drag the word across to hear the word pronounced in the other language. Children played with each version for 5 minutes. We provided phones with the SpeechBlocks apps pre-installed.

During play, the phones were instrumented to record every finger tap and interaction that occurred within the app. These data logs provided a level of detail that allowed us to recreate the child's play session by completely reconstructing everything that happened on the child's screen. We used these logs to analyze what words the child constructed, the word and letter components that the child used to make these words, how many times the words were tapped and heard by the child, and, for BSB, what language(s) the child heard these words in.

We also took observational notes of engagement during play, noting any signs of frustration, excitement, boredom, and any dialogue that occurred throughout the play sessions. After children played with both versions of the app, we conducted a feedback questionnaire, recording data on their experiences and preferences.

The self-expressive nature of SpeechBlocks allows children to make personally meaningful words [39]. We identified personally meaningful words through qualitative analysis. Children's expressions of intent and reactions of excitement or self-efficacy around the words they made were recorded through our observational notes and the feedback questionnaire. We used the log data to code for personally meaningful words which are typically names, sentences, or expressions rather than nonsense words or objects [39].

RESULTS

We used a two-tail paired-sample t-test to determine whether the differences between the two conditions (MSB and BSB) were statistically significant and used the Clopper-Pearson method to compute 95% confidence intervals for the questionnaire responses. We examined both user-created words, meaning words that contain at least one letter-block that originated in the letter drawer, and system-created words, meaning words that contain only words and parts of words that originated as pre-assembled words in the word drawer.

Differences in Modes of Interaction

We looked at the two main modes of interaction in MSB and BSB: (1) Creating words by splitting or merging existing words or by adding letter blocks to existing words and (2) tapping on words to hear them pronounced in a given language. There was no significant difference in the total number of words that each child played with. However, on average,

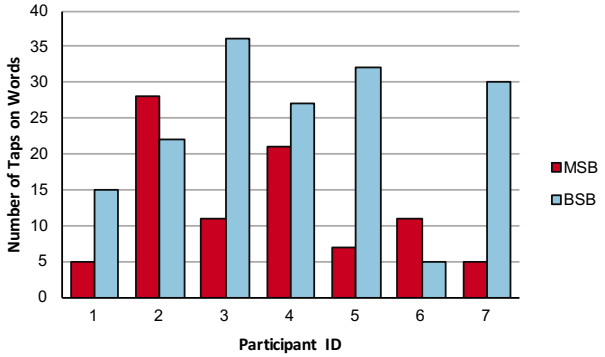

Figure 4: Comparison of the number of taps participants made on words in Monolingual SpeechBlocks (MSB) and Bilingual SpeechBlocks (BSB).

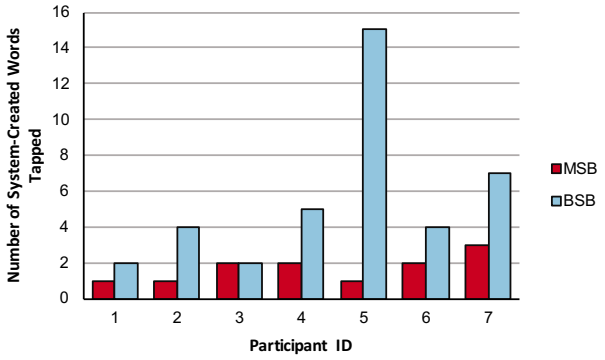

Figure 5: Comparison of the number of system-created words participants tapped in Monolingual SpeechBlocks (MSB) and Bilingual SpeechBlocks (BSB).

children tapped on words 1.9 times more in BSB than MSB (Figure 4). Moreover, they tapped on system words 3.25 times more in the BSB condition than MSB (Figure 5). Although these differences were not significant, due to the small sample size (n=7) we still find these results noteworthy.

The difference in number of taps resulted from children frequently tapping on the words to hear them in both languages, as they dragged the words across the midline. They exhibited this behavior with 34% of words they tapped on in BSB (see Figure 6). These observations indicate that BSB introduced a new affordance of playful interaction for children: comparing and contrasting pronunciations of the words in two languages. This affordance is important in light of the previously mentioned findings regarding negative transfer for bilingual children. In this way, the nature of children's wordplay changed because the BSB design included the ability to hear words pronounced in two different ways (Spanish and English), and children seemed to use this feature often.

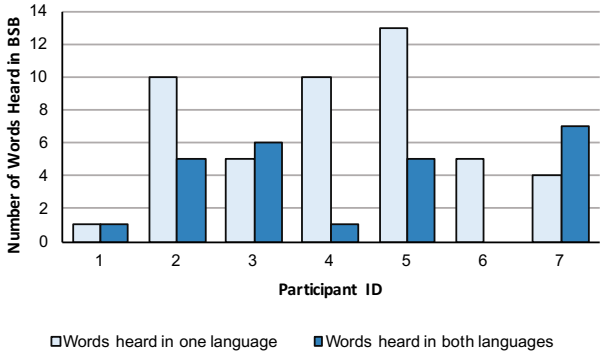

Figure 6: Comparison of the words participants heard in one language (either Spanish or English) and the words they heard in both languages (Spanish and English) during play with Bilingual SpeechBlocks (BSB).

Indications of Personal Meaningfulness

Personally meaningful words tend to be names, sentences, and expressions. We manually annotated the number of times a proper noun such as a child's name, character name (e.g. the character name "kingkong"), or name of an object (e.g. the name of the game "minecraft"). Sentences (e.g. "I love my mom" which was counted as one word), and expressions (e.g. *mamá*, meaning "mom" in Spanish) were also annotated as personally meaningful words. There was no significant difference between the number of personally meaningful words created in MSB and BSB.

However, qualitatively, the researchers observed that the nature of how some children created their personally meaningful words seemed tied to which side of the canvas they were constructing the word on. For example, one child who speaks English with her sister at home continually spelled words on the English half of the app and then moved the words over to the Spanish half to see how they were pronounced in Spanish. However, when the child wrote her own name, it was the only word she created on the Spanish canvas.

Researchers also observed that a few children who only spoke Spanish at home tended to create words on the Spanish half of the canvas and then moved over to the English half. One such child made almost all of his words in the Spanish canvas, but then decided to try and recreate his name in the English canvas. Halfway through his name, the speech synthesizer pronounced the first six letters of his name, which made up a real word when pronounced in English, but not when pronounced in Spanish. The child was very confused and exclaimed, "What?!", possibly because he had never heard the first half of his name pronounced in English before. He then proceeded to check that he was spelling his own name correctly. One possible reason for these observations is that the ability to make a word that can be pronounced in either language created an interesting dynamic that may be reflective of the child's personal identification with one language or another, as well as how a child categorizes certain concepts or words.

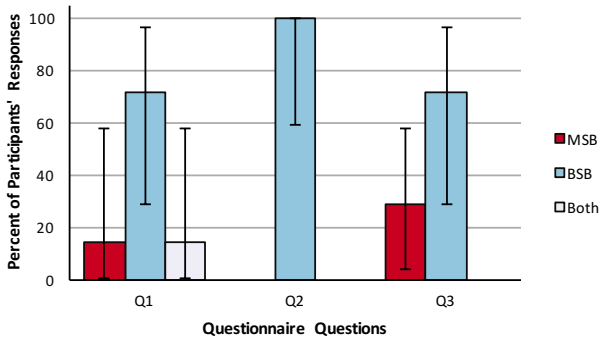

Figure 7: Percentage of participants that chose Monolingual SpeechBlocks (MSB), Bilingual SpeechBlocks (BSB), or both versions in their end-of-study feedback questionnaire responses. **(Q1)** Which version of the game was your favorite? **(Q2)** If you had to play this game again, which version of the game would you like to play again? **(Q3)** If you were playing this game at home, which version of the game would you like to play? For all three questions, the participants were presented with three options: Monolingual SpeechBlocks (MSB), Bilingual SpeechBlocks (BSB), or both versions.

Children's Engagement

To examine children's engagement, data on finger taps was used to determine children's sustained interaction within the app, and both MSB and BSB had sustained engagement, or taps, throughout the play sessions for all seven children. We posed three questionnaire questions to understand how the children perceived their experiences, serving as proxies for what experiences they found engaging during their play. When asked which version of the app was their favorite, 71% of children said BSB was their favorite version (Q1 in Figure 7). Additionally, when asked which version of the app they would rather play again, 100% of the children said that they would rather play BSB again than MSB (Q2 in Figure 7) and when asked which version they would like to play at home, 71% of children said that they would like to play BSB at home (Q3 in Figure 7). This suggests that these children may have perceived their experiences with BSB as more engaging than MSB. Note that due to our small sample size, we cannot establish the Q1 and Q3 results with confidence and a further study with a larger sample size needs to be conducted in order to understand whether these trends will be replicable.

DISCUSSION

Engagement and Funny Voices

As shown in the results, children seemed to perceive their experiences with BSB as more engaging. One possible reason for this is that the nature of wordplay is different in the BSB version than the MSB version. These new affordances may have influenced children to perceive their experience with BSB as more engaging. Children used BSB to spell words in one language and then hear how they are pronounced in another. The children did not seem to be confused by the changed pronunciation when the word crossed the midline. Instead, the unexpectedness of the pronunciations seemed to result in what we call a "funny voices" effect, which, according to observation notes, seemed to engage children and expose them to how a familiar word is differentiated between the two languages. This observation is similar to research by Tarone [41] and Bell [2], which encourages teachers to use funny voices to increase student interest and participation in language learning. Children seemed to especially appreciate the effect of the funny voices for nonsense words. For example, when asked to explain why she liked BSB, one child said she really liked being able to tap and have the app say any word she wanted in Spanish and English. She then elaborated that it was especially fun to mix up the words and hear the funny voices.

The ability for children to explore with these funny voices incorporated a playful, humorous nature into the app that research shows helps children learn [34, 12]. For example, the English word "ball" sounds like "baye" when pronounced in Spanish. This effect encourages children to explore how a word sounds in both languages, an important aspect of language differentiation for bilingual learners [10, 8]. These funny voices may have also made the interactions within BSB more memorable, influencing children to perceive that they were more engaged and made cooler words when playing with BSB than with MSB.

Stories

While playing with the bilingual version, there was one child who shared a personal story that was directly prompted by the design of BSB. During his play session with BSB, he spelled out his last name in the Spanish canvas and then removed the "s" from his name when he moved it to the English side. He then proceeded to tell the researcher a story about how when his family moved to the United States, they dropped the "s" in their last name. The dual-language nature of BSB is likely to be especially powerful for bilingual children because it pronounces personally relatable words, like names, in the child's home language.

This example and the qualitative examples of children's discussions around the words they created in BSB (see Results) present implications for the design and development of bilingual literacy apps, just as, if not more specifically than monolingual apps, to be open-ended. Each child has a unique level of bi-literacy, using a different combination of their languages for varying contexts (e.g. school, home, friends). It is important that the design remains open-ended to account for these variations and allow children to express themselves using both languages in their repertoire.

Family Co-Engagement

One observation that we did not initially account for in our study design was the level of co-engagement of Spanish-speaking parents during the BSB condition. We observed and coded three main types of parental engagement during the sessions: asking questions, sharing stories, and co-engaging in play. We define "asking questions" as questions that were initiated by the parent, addressed to the child, and referred to either the app or the child's play. We define "sharing stories"

as parent-initiated conversations addressed to either the child or researchers about personal anecdotes or experiences related to the app or play. We define "co-engaging in play" as the parent interacting with the child and/or the app (verbally communicating or physically tapping on the app) in order to effect the play that happens on the screen.

Upon review of our observation notes, parents tended to co-engage more and share stories during their children's BSB play sessions, and not engage during their children's MSB play. Parents' interactions with their children were mainly in Spanish. In two particular cases, while the children played with MSB, their mothers were on their own personal phones. However, in both cases, when the children played with BSB, their mothers put down their personal phones and co-engaged with their children in playing with the app. For example, one of the mothers asked her son "What's another word? What does *mapa* mean in English?" The other mother asked her daughter what the meanings of some of the words she created were. This began a conversation between the two of them in Spanish about what the child was creating with the app.

After hearing BSB pronounce a Spanish word, another mother immediately leaned over to look at what her daughter was doing and told the researcher, "It is very interesting. For me, I didn't learn (how to write in) my own language. So it's (BSB) very interesting." The mother and daughter then proceeded to play together and make new words with the game.

As shown in the results, when asked which version of the app they would rather play again and why, all of the children preferred BSB. One child replied that BSB was her favorite because she could play it with her mother. Another said that he enjoyed BSB more than MSB because he could "translate things" for his mother using the app. From these observations, we saw that Spanish-speaking parents were more attentive when their child was playing with BSB.

Given the importance of family co-engagement in children's learning, the active participation of parents during BSB play sessions may help improve children's learning when using the bilingual vs. the monolingual version of SpeechBlocks. The open-ended nature of the SpeechBlocks design coupled with the bilingual features of the BSB app, seemed to encourage organic interactions between parents and children around their creations. This may have important implications for the design of future bilingual literacy apps to incorporate ways for parents to naturally co-engage with their children, and is an area of future study for BSB.

Implications for Design of Bilingual Learning Apps

This work presents implications for the design of children's bilingual learning apps and games. Our results and examples highlight the importance of an open-ended and evidence-based design that is informed by how bilingual children learn literacy skills. By accounting for children's varying levels of biliteracy through the open-endedness of our design, we found new affordances for children to express themselves in both languages. Additionally, the dual-language design of BSB was informed by the research on how children differentiate between overlapping orthographies. Our results showed that children differentiated between the pronunciation of words by tapping to hear them in both languages. Therefore, it is important for designers to consider how bilingual children learn literacy skills—which is different than learning a second language—and incorporate this research into how they design learning apps for bilingual children. As there is a lack of apps that specifically target bilingual children's literacy learning, we hope that this work can serve as a starting point for designers and developers to create apps for this growing population.

Limitations and Future Directions

Some of the limitations of the design were already addressed above in the design section of this paper. However, we also note some limitations to the exploratory pilot study. First, the study was conducted completely in English, which may have introduced a priming effect, influencing the children to create more English words for both conditions. For example, both researchers involved in conducting the study were native English speakers, and spoke to the children and parents in English. The assessments and instructions were all conducted in English, priming the child to respond in English, even when talking about BSB and the ability to make words in English or Spanish.

Second, the study was conducted at the children's school, which was an English-speaking school (not bilingual), and despite some of the Spanish-speaking parents being present, this may have influenced the children through a context effect. It is common for bilingual children to separate who they use each language with, and where they use each language [9]. When these contexts mix, for example, when a teacher tries to speak with a bilingual child in their home language at school, it can often confuse children and, especially for younger children, they may actually abstain from speaking in their home language at school [9]. It is possible that conducting this study at the children's English-speaking school could have influenced them to make more English words than Spanish words due to the English-dominant nature of the context.

In order to understand whether these language limitations influenced the words children made, we would like to continue this research by conducting a study where half of the participants receive the study procedure in English and half receive it in Spanish. Additionally, we plan to conduct a similar pilot in the home setting or a language neutral setting, rather than the children's school.

Another language limitation was that we only examined the difference between a monolingual English version of the app and a bilingual (Spanish-English) version of the app for bilingual Spanish-English speakers. In order to understand the true affordances of a bilingual app over a monolingual app (instead of just a monolingual English app), we would need to also create a monolingual Spanish version of SpeechBlocks. To continue this research, it would be important to see if similar trends were found for the bilingual version of SpeechBlocks compared to both monolingual versions (English and Spanish, respectively), in order to determine if it was the introduction of both languages in one canvas, or simply that children preferred one language over the other in different contexts.

Lastly, another limitation is that we did not design the study to examine the extent to which parents co-engaged during their children's play with SpeechBlocks. Although one of the affordances of both MSB and BSB is that the immediate, auditory feedback is intended to encourage social engagement along with providing feedback to the child, we did not expect there to be so much interest from the parents. Since research shows that parental involvement in children's learning is an important part of children's reading development, a future direction for this work would be to design the next pilot study to accurately measure parents' reactions and levels of co-engagement.

CONCLUSION

In response to the lack of open-ended literacy learning apps for bilingual children, we created BSB to provide a constructionist environment for children to explore the foundations of literacy by tinkering with letter-to-sound mappings in both Spanish and English. We designed, built, and ran an exploratory pilot study of the app with seven bilingual children between the ages of 5 to 9 years old. Overall, children seemed to be engaged while playing both versions of SpeechBlocks. However, BSB presented different affordances than MSB, namely that the ability for children to differentiate between Spanish and English changed the way they tapped on words in order to hear familiar words pronounced in "funny voices" and increased engagement with system-created words. Additionally, BSB presented opportunities for parents to co-engage with their children while playing with the app.

As a next step of this work, we want to see whether these affordances of BSB will be present in a larger sample of bilingual children. We aim to conduct further studies that address our limitations and use standardized assessment measures to study whether BSB can serve as a neutral platform to assess children's ability to differentiate between two languages. We hope that this work will be the first of many open-ended apps to be designed and tested for bilingual children's literacy learning.

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