Final Report: POPSign (v2)

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# ABSTRACT

The majority of deaf children are born to hearing parents [5], which creates a crucial need for American Sign Language (ASL) training for new speakers. In this report the continued development of a mobile game called POPSign, designed to teach American Sign Language to parents of deaf children, is described. After development of an improved version of the game using the cross platform Unity3D game development software, a think-aloud user evaluation was performed on 19 participants to determine the usefulness and usability of POPSign. Users indicated that the game is a fun, and useful way to learn sign language, although it still needs minor improvements before it can be deployed. Proposed features for future development are presented based on user feedback and the opinions of the development team.

# INTRODUCTION

Between 90 and 95% of deaf children are born to hearing parents in the United States [5]. Most of these parents have no previous experience with American Sign Language and must learn it in order to communicate with their children [6]. Deaf children born to hearing parents can experience delays in language learning, which can lead to reductions in verbal ability [8]. A mobile app is an ideal way for busy parents to practice ASL [6]. An Android game called POPSign was developed at the Georgia Institute of Technology by researchers in the Human-Computer Interaction department to help parents of deaf children learn ASL [4]. The original POPSign prototype possessed certain design and user experience weaknesses. This report describes the development of a new version of POPSign in the Unity3D game development environment that introduces more vocabulary, optimized video, and new ways to practice and learn words. This application is being developed to improve and assess POPSign so that parents of deaf children will have a powerful tool to to help them learn ASL through an engaging and addictive mobile game.

# PREVious work

**SMARTSign**

Kimberly Xu, a student at Georgia Institute of Technology, notes in her PHD dissertation that hearing parents with deaf children face significant challenges [6]. Learning sign language can be a difficult task for parents who may not have the time or resources to attend physical classes. Along with this, static books and images do little to help parents master ASL. Xu hypothesized that if parents could learn sign language on their mobile devices, many of these issues would be mitigated. Xu went on to create an app called SMARTSign to test this hypothesis. The app helps parents learn ASL vocabulary by enabling users to search for ASL sign videos, study with a quiz interface, and practice by signing in front of the phone camera. The application used a subset of the MacAurther-Bates Communicative Development Inventory, which is a list of important words that children often learn during verbal development [7].

Xu’s research resulted in a number of important findings. One interesting discovery was that video quality did not impact the ability of users to recognize and reproduce signs. Other discoveries were less encouraging: while SMARTSign received positive user feedback, the “Recorder” function, where signs are performed in front of the camera, was criticized. Users found that this was an awkward way of practicing signs, and as a result, saw little improvement in actual sign reproduction after using the app. This functionality was implemented in an attempt to provide an answer to research suggesting that users still have difficulty physically performing signs that they can already recognize on phones [10].

**POPSign**

Celeste Mason, advised by Dr. Thad Starner, helped create an application called POPSign, inspired by Xu’s research [4]. Since use of the SMARTSign app diminished significantly over time, POPSign was created to make the process of learning signs on mobile devices more engaging, and addictive. POPSign was built using the open-source code from a popular Android “bubble bursting” game called Frozen Bubble. Mason found that users reported their POPSign experience as enjoyable overall, and were enthusiastic about using the game. Like SMARTSign, evaluations of POPSign still couldn’t provide evidence that sign recognition in the app would result in greater sign reproduction in the real world.

In Mason’s POPSign prototype, users are shown a set of multi-colored bubbles at the top of the game screen. Players must shoot a ball at a set of similarly colored balls to make them disappear. Each bubble has a text string inside of it, representing a sign language vocabulary word for that level. At the bottom of the screen, there is a looping ASL video. To know which color bubble will be shot, users must learn the definition of the sign language word being shown in the video. This hybrid game dynamic allows users to learn sign language while playing an addictive mobile game.

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**Figure 1. Original POPSign UI [4].**

# CURRENT WORK

The first prototype of a new version of POPSign has been created in Unity3D. A bubble popper game template was purchased from the Unity3D asset store. The template was modified to disable unnecessary features. For the purposes of the initial prototype, a set of 40 ASL word videos were chosen from the MacAurther-Bates index and arranged into eight sets of five words each. Words were placed in relevant groups, based on which words would be commonly used in similar contexts, and sentences.

**Video implementation**

The team researched the best ways to implement the looping ASL videos in the Unity3D version of POPSign, and determined that the use of jpeg pictures flipped continuously to create the illusion of video would allow the application to be exported to the widest variety of platforms, without the need for 3rd party video plugins. Ffmepeg, a command-line tool, was used to export jpeg frames from a collection of ASL videos from the chosen word sets. After this, ImageMagick, another command-line tool, was used to crop and resize the images. ImageMagick was also used to re-color the videos to black and white for aesthetic purposes.

**New modifications**

The game template was modified to include the features of the original POPSign game, along with new features to increase the usefulness of the game as a method for learning ASL. The new features were:

1. Dynamic json word sets. Each level has a json file that assigns a word set to it. The original POPSign prototype created by Mason had all of the words hard-coded into it for evaluation purposes, and due to the use of only a few vocabulary words was not ready for daily use or app store deployment. Dynamic words sets allow POPSign to support the addition new vocabulary



**Figure 2. Updated POPSign UI.**

in the future, without the need for major code modifications.

1. The preview screen. The new version of the application implements a preview screen that appears before each level. This screen allows users to practice words before entering a level. In the original POPSign game, users had to learn words during gameplay, which required initial experimentation to determine definitions. The preview screen does away with this by allowing users to learn a set of words before a level starts. The preview screen also helps users understand how to play the game, and encourages them to physically practice the sign language vocabulary before each level.
2. Cross-platform development. Development in Unity3D makes it feasible to distribute POPSign on many platforms, including Android, IOS, Mac, Windows, and web browsers.
3. UI Re-design. The user interface has been re-designed to match the quality of popular mobile games. Each UI element was re-drawn. The original application used dated graphics and sound effects that may have led to a less engaging experience. See Figure 1 for an example of the original UI, and Figure 2 for an example of the update.
4. Optimized video. The jpegs optimized with ImageMagick have a smaller file size than the images used in the original POPSign prototype.

**User evaluations**

After implementing these changes, user evaluations were completed using a think-aloud procedure and a follow-up survey. 19 participants between the ages of 18 and 34 were selected in the student center at Georgia Institute of Technology, based on willingness to participate. Users in the think-aloud were instructed to play the first level of the application. Participants were also asked to explain the purpose of the new preview screen to evaluate the usefulness of this new addition to the POPSign gameplay.

# Discussion

**Unity3D**

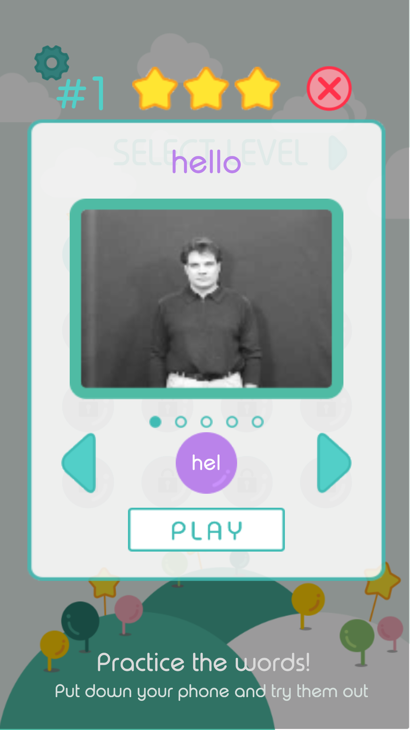
The team’s decision to use Unity3D to develop the application came in part after negative experiences developing the application with the original Android code base. For the first few weeks of the project, the team explored the original Android POPSign code. After struggling with cryptic logic, deprecated tools, bugs, and difficulty transitioning the project into modern Android development environments, the team decided to start fresh, using Unity3D.

Possible downsides of Unity that the team researched were royalties and licensing costs. The bubble-shooter asset to jump-start development cost $40, and legally should be purchased again for the account that will develop the application in the future [1, 2]. This purchase does not need to be made for every account developing POPSign, but once for each team of developers. Unity3D is free for developers who do not work for a company that takes in more than $100,000 each year [3]. Georgia Tech unfortunately does not fall under this bracket, so if development of future iterations of the application is handed off to Georgia tech researchers or faculty, a Pro license will need to be purchased. It is possible that Georgia Tech already pays for Unity3D Pro licenses for classes in the Digital Media lab.

Development in Unity3D proved to be simpler, and more intuitive for each of the developers. In Unity3D, development takes place in both a scripting environment where code is written, and a visual environment where the elements and objects in the project can be manipulated through the Unity3D GUI interface. The ability to visually modify elements in the project without needing to write code allowed the team to rapidly prototype additions to the POPSign application.

**Think-aloud user evaluation**

User evaluations of the application revealed a number of useful findings. The think-aloud procedure performed on participants resulted in important qualitative data. One finding was that the preview screen was sufficient for some users to understand the purpose of the game, but insufficient for others. The preview screen contains a preview of the words that will be in the level, along with an image showing what each bubble will look like for each word in the game. Nearly all of the users evaluated who chose to click the “next” or “previous” buttons on the preview screen quickly discovered the purpose of the game. Upon flipping through the words, users were generally able to deduce that the words depicted would be represented by colored bubbles in the level, with abbreviated word names inside. These users, upon entering the level, performed very well. Other users who did not click through the words on



**Figure 3. The preview screen.**

the preview screen did not perform as well. Aside from the fact that they did not have time to memorize the words that would be in the level, upon entering the game they were generally more confused about the actual gameplay. The researchers concluded that changing the preview screen to encourage users to click through the words before clicking the play button would make the game easier to understand. This could be implemented by not giving users the option of playing the level until the words have been cycled through on the preview page. Figure 3 shows an image of the preview screen. Aside from this usability issue, the think-aloud sessions generally revealed that users had very positive perceptions of the game, commonly praising its quality and innovation.

**User survey results**

The survey given to users after the think-aloud revealed that users were enthusiastic about the game, and that the game needs some minor modifications to reduce the initial learning curve. The survey was broken up into three parts: background information, usefulness of the game, and usability of the game.

*Survey: background information section*

The background information section showed that participant ages ranged from 18 to 34, with an average age of 24. Since POPSign was designed with young parents in mind, this fits our target user stakeholder age. Users in the survey had little or no experience with sign language, and had very few mobile games on their phones, with over 90% of participants reporting five or less games installed. Most participants were not avid mobile game players, playing one mobile game a week or less.

*Survey: game usefulness section*

The second portion of the survey revealed positive user perceptions of the game. On the first six-point semantic differential question users reported an average value of 4.89, where 1 indicates “I did not like POPSign at all” and 6 indicates “I enjoyed POPSign very much.” The next question had an average value of 5.16, where 1 indicated “If I needed to learn sign language I would not want to play this game at all” and 6 indicated “If I needed to learn sign language I would want to play this game very often.” A likert-type question stating “I would invite others who are learning sign language to play POPSign” received an average value of 5.47 out of 6, indicating that users strongly agreed with the statement. Favorable answers to these three questions show that users have positive perceptions of the application. This section of the survey also asked users to recall and reproduce as many ASL words as they could from the words used in the level. Although most survey-takers refrained from actually physically practicing the words, participants reported remembering an average of 3.58 out of the 5 total words in the level. Although this is a self-reported measure, it means that participants believed that they had learned most of the words in the level.

*Survey: game usability section*

The final section of the survey was included to determine if the application was easy to use. Through likert-type and semantic differential questions users indicated that POPsign was easy to use, easy learn without having someone teach you how to play, and free of glitches. Questions assessing whether or not POPSign needs to included an in-game tutorial to explain how the game works had mixed answers. The likert-type question “POPSign needs an in-game tutorial that explains how to play” had an average value of 3.89, indicating that most users leaned towards supporting the addition of a tutorial. Questions assessing the new preview screen revealed that it significantly helps users understand how to play the game, but did not necessarily motivate users to physically try to reproduce the words being previewed. The preview screen has a note at the bottom of the screen that says “Practice the words! Put down your phone and try them out.” Over 60% of participants responded that they had not seen this note that encourages practicing words.

The usability section contained two open-ended questions to get qualitative feedback. The first question was “What confused you in the game?” Users indicated that they were confused by the practice page, how to play the game for the first time without a tutorial, and the bubble switching mechanism in the gameplay. Users found the preview screen confusing because they were not adequately instructed to click through and practice the words displayed. Some users were also confused by the transition from the preview screen into the gameplay, which happened quickly without a sufficient explanation of what was expected of users in the next phase of the game. Some users also noted that the way to win the level was not intuitive: in the new version of POPSign levels are completed by clearing a certain number of bubbles in the top row of the bubble grid. This gameplay mechanic is simple, but without explanation may be confusing.

The second question was “What are your recommendations to improve the game?” Most of the participants reported that the game needs a tutorial to explain how to play. Other participants noted that the preview screen would make the game easier to understand if emphasis was placed on pressing the “next” button to cycle through the videos before playing the level, rather than having the “play” button front and center, which leads users to enter the level before they are ready to play it. These responses align with the conclusions reached by the evaluators during the think-aloud procedure.

# Future work

**Changes suggested by users**

Results from the think-aloud and user surveys have revealed two primary modifications that should be made to optimize the usefulness and usability of the game.

1. Modifications to the preview screen. Although this screen was helpful for users, many users simply pressed “play” upon reaching this screen, and didn’t use it for its intended purpose of learning and practicing words before entering a level. The preview screen should be modified so that the play button is made less prominent, or invisible until users have cycled through each of the words that will be in the upcoming level.
2. A tutorial. The team wanted to assess if the inclusion of a preview screen would make a tutorial unnecessary. Users have indicated that a tutorial is still necessary for learning how to use the game. Although the preview screen helps users discover the connection between the videos and the ball colors, some things cannot be explained on the preview screen. Things like the switching mechanic, how many levels will have the same set of words, and how to win a level should be explained separately. This could easily be completed with a “slideshow” tutorial, with annotated images explaining each of these areas of confusion. The addition of an in-game tutorial was also a common suggestion during user evaluations of the original Android POPSign prototype created by Mason [4].

**Changes suggested by development team**

Aside from these two necessary changes revealed by users, there are a number of other changes that the developers have proposed:

1. Platform testing. The application has been tested on Android because that is the primary platform that will be used by end users. Since the application was created in Unity3D with cross-platform development in mind, it would be useful to test and eventually deploy it on IOS, and other platforms, so that it can be used by a greater number of people.
2. Downloadable new word sets. Right now, the game parses and includes word sets based on json files unique to each level. In the future, it would be beneficial to give users the ability to download new words sets, and even new levels, to be included in the game. The current application only uses 40 words, but could support many more.
3. Randomization and level/word independence. In the current prototype, levels and words are coupled by the json file for each level. It would be beneficial to de-couple these so that the current 32 levels in the game could be used with diverse word sets. With this modification, users would be able to select a word set from a menu and play levels with that word set. This would allow thousands of words to be easily integrated into the application, and would require few modifications to the current code base.
4. Progress visualization. This would give users the ability to monitor which words they have practiced the most, and which ones they need to practice more.
5. Additional incentives to play the game. Although users were enthusiastic about POPSign, it’s possible that these feelings could fall off over time. It may be beneficial to look into additional things to motivate users, like networked leaderboards, badges, or other features in the game that add variety and strategy.
6. Additional user evaluations to assess word replication ability. One of the primary concerns with the original POPSign and SMARTSign prototypes was the fact that being able to recognize words does not necessarily indicate ability to perform them. In the think-aloud for the new version of POPSign, evaluators were encouraged by the fact that some of the participants physically practiced the words on the preview screen. Additional evaluations should be completed to determine if users who try out the words are able to recall and perform more words than people who play the game without physically practicing the words. If these players do have an advantage, the preview screen should be modified to better instruct users to try out words before playing a level.

# Conclusion

Learning ASL is unlike learning any other language. Parents of deaf children are faced with the daunting task of learning a language that cannot be effectively studied using traditional language-learning tools. SMARTSign and the initial POPSign prototype demonstrated the potential of utilizing mobile platforms to teach sign language to people with no ASL exposure in an engaging, visual manner. The new version of POPSign has begun the process of turning the application into a store-ready game that can help parents learn sign language faster.

Users have indicated that the new version of POPSign is a valid way to learn ASL. Upon reaching the preview screen at the start of a level, one participant immediately understood the purpose of the game and explained it to the evaluators. He looked down at the text on the preview screen that instructs users to practice the words before playing the level, held his phone out with one hand, and signed each of the words with the other hand. Upon entering the game, he completed the level in a matter of seconds. He seemed excited, and said that he was currently studying sign language using a different mobile application, and would be thrilled to use POPSign if it could be downloaded in the app store. Feedback like this has led the developers to conclude that POPSign has great potential, and further development should take place to help parents bridge the divide between the hearing world, and the silent world.

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