Sign Town: An Interactive Game to Teach American Sign Language

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ABSTRACT
Sign Town is an interactive game to teach elementary-aged students about American Sign Language (ASL). The game scaffolds learning the language and each level has its own challenge to excite users. It starts with simple weather sentences in level 1, and as the user navigates the world through utilizing ASL, Leap Motion technology allows users to understand when they are using the correct signs.

Author Keywords
Tangible Interaction Design; American Sign Language; Leap Motion Sensor; Elementary-aged Children; Interactive Games;

ACM Classification Keywords
Design. Game. American Sign Language. K-12 Education. Children.

INTRODUCTION
There are one million functionally deaf individuals in the United States [17], and American Sign Language (ASL) is one of the most common modes of communication for this population. No reliable data is available regarding the number of users of ASL, both within and outside of the hard of hearing population [18], yet less than 650 public schools offer courses in the subject [20], indicating a large disconnect between hearing and non-hearing populations. A greater literacy of ASL would increase social connections and communication between these groups. In addition, learning ASL provides many cognitive benefits to children, including better spoken and written English language development. Individuals who are fluent in ASL are shown to have greater English literacy skills, particularly regarding "verbal communication intentions, mastery of rules of syntax, and strong skills in vocabulary and semantics." Learning ASL also provides many of the same benefits that traditional bilingualism brings; in particular, positively influencing the white matter in an individual's brain [23].

Sign Town is an interactive game for elementary-aged students so the next generation grows up learning the language. This would bring more awareness and connection to Deaf communities, while providing cognitive benefits for the individual users. The gaming aspect will increase user engagement and aid in accomplishing learning outcomes.

Learning ASL enables all individuals to foster greater human connections. Currently mobile apps, youtube videos, and websites are the best available ASL teachers. While one can learn individual words and letters through these mediums, there is a lack of opportunity to develop conversational skills due to the one-directionality of these applications. Users can see what they are supposed to do, but they cannot receive feedback on their motions. ASL is based on nuances in facial expressions and hand gestures, and today's tools can neither demonstrate nor detect these nuances. American Sign Language is an inherently physical medium, and the tool used to teach it should have a direct relationship with this physicality. Current ASL learning applications do not require students to perform the signs, instead they rely on observations of the signs, hindering user engagement and learning outcomes [3].

One steep challenge to learning ASL at a conversational level is being able to differentiate the essential and non-essential movements. In addition, ASL requires one to use their entire body (hands, face, torso) to communicate. Most students are not used to doing so and, as a result, can feel uncomfortable or shy when learning ASL, causing hesitancy and inhibiting the learning process [16]. The interactive game we developed requires students to engage their entire body to move in a more natural setting to make them less self-conscious.

Design Goals
Our broad goal was to develop an interactive game that builds confidence in elementary-aged kids' ability to communicate in ASL. We strove to make a gaming experience that is enjoyable and immersive while aiding the learning process. A guiding design principle was to create a responsive system - our game would be able to evaluate the correctness of the signs that the user performs while providing feedback. We also wanted this game to introduce users to simple sentence-building in ASL as a first step to conversationality. Many tools currently on the market focus only on building vocabulary, leaving a white space

that this game can fill. Ultimately we hope that by developing this game for younger children they will be excited to learn the language and we can create a generation who speak ASL more fluently.

Challenges of ASL

Sign Language is a non-verbal language based entirely in hand signs, facial expression, and the movement of hands. According to the Foreign Service and Defense Language Institute, which categorizes languages according to their level of difficulty for native English speakers, ASL is a category II on a scale of zero to five [13]. This means that in about 480-720 hours, a person can speak the routine social demands and limited work terms of ASL. While no official hour count has been done, Rhonda Jacobs, author of "Just How Hard Is It to Learn ASL: The Case for ASL as a Truly Foreign Sign Language", disagrees with the categorization. She believes ASL should be a category IV language, indicating it takes approximately 1320 hours to become level 2 proficient in it. This is a dramatic difference that would suggest ASL is one of the hardest foreign languages to learn. Regardless of where it falls in the categorization, ASL is a unique second language and there are unique challenges affiliated with learning it.

Two of the biggest challenges of learning ASL are the difference in syntax and grammatical structure compared to English and the absence of self-monitoring. People learning a second language transfer linguistic rules from their first language into the language they are learning [5]. Oftentimes this helps when learning other languages, but ASL has a different grammatical structure that does not allow this transfer of knowledge. Kemp [13] mentions that this is a common issue among beginner learners. One example of this is the English sentence "it is sunny outside". While this sentence makes perfect grammatical sense in English, in sign language, the same sentence is the phrase "outside sunny". Another challenge of learning ASL is the lack of ability to self-monitor. When communicating in a spoken language, one can hear the words coming out of their own mouth and judge if what they are saying matches the message they intended to deliver. Since ASL is not a spoken language, people lose this awareness and ability to self monitor when speaking in ASL. This can be a notable challenge for English speakers and they often try to cope with this by simultaneously speaking the words they are signing [13].

A third challenge for ASL beginners is learning the cultural behaviors associated with the language. To learn ASL, learners must be taught not only vocabulary and phrases, but also behaviors such as "attention-getting techniques, back-channeling, and eye contact" [13]. Since a lot of ASL is shown in the face, these behaviors are important to learn.

Learning a foreign language

Despite all these differences between other second languages and ASL, one significant similarity is that ASL, like other languages, is best learned at a young age [15]. We chose to focus on elementary aged children because this is a prime age to teach a second language. We have all heard the mantra regarding children soaking up information 'like a sponge' especially as it pertains to learning a language, whereas adults have a more difficult time with this process. Cognitively, this happens because we lose brain plasticity over time.

Designing for Young Kids

We turned to other tangible interfaces for elementary aged children to determine important design features for this age group. SMILE, an immersive learning game for math and science education that utilizes a 3D fantasy environment, had eleven design principles [26]. The goal was to design an engaging game for this aged group, and they found that starting with a shared story context among users and a clear goal for the game maintained interest early on. Across the rest of game play, Villani and Wright [26] utilized principles like rewarding for correctness, scaling up difficulty as levels advanced, and providing hints rather than answers to questions. To further this idea that providing engaging gameplay matters, Moser et. al [20] led a workshop based on the idea and said that "when playing [games] voluntarily, gaming is an end in itself rather than a vehicle to learn." While Sign Town is a game intended for school use, every child can either participate constructively or choose not to participate and disrupt. We attempted to make the game fun and the learning as present but underrated as possible for users.

RELATED WORK

There are many existing ASL apps and interfaces that attempt to teach individuals the language and improve communication between hearing and Deaf people. Only a few make the experience social, incorporate the body, or address complex grammatical structures. In terms of technology that attempts to be responsive, it is a tradeoff between the Leap Motion and Kinect.

One related work is SmartSignPlay, a smartphone application designed to improve communication between deaf children and their hearing parents. In this app, users navigate an avatar through a virtual home and learn the signs for the objects inside. The objects are contextualized and users can choose which objects they want to learn the signs for [7]. After interacting with the objects, users are tested for their understanding of the sign. This test consists of choosing the correct handshape and direction of motion from a preset list. While users are encouraged to practices the signs they are learning, the testing solely consists of multiple choice questions. The application contextualization is a great way to help locate signs you want to know, but ultimately the results show that users could only recall less than four to five signs on average.

Another example of existing technologies is VisualComm, an interface that tries to improve communication between hearing and deaf individuals through a Kinect and sign language recognition technology [5]. This tool is one of the first that allows for two-way communication, and it opens up the opportunity for deaf people to communicate with an external community. It essentially acts as a translator taking the signs and making them verbal or vice versa, depending on which community you belong to. With their small sample size, Chai et. al [5] found that this broke down barriers as they hoped. At the time the paper was published however, only a small sample of Chinese characters were available on the interface. They found it very difficult to make the Kinect recognize the signs, and that challenge only increases as the number of sign languages VisualComm recognizes increases.

A third related work is CopyCat, which uses the kinect for sign language recognition as an interactive game for deaf children [3]. CopyCat began as a system that tracks hand motions in the game using gloves with accelerometers, but once the Kinect was introduced, the team found that it worked just as well to verify hand motions. A caveat to that is that Kinect only works while the user is standing, which changes the type of interaction between the user and the system. While the use of Kinect leads to better verification, this is certainly a tradeoff. In the game itself, users must sign a three-word sentence correctly to the hero characters to advance levels. Our interactive game is similar to CopyCat in its' use of signing to pass an obstacle, but our targeted users are hearing English speakers who want to learn ASL.

In our background research of existing work, we saw that the majority of projects focusing on ASL recognition in the past used the Kinect because of its depth sensing capability, which allows full body recognition. The tradeoff however is that the Kinect cannot pick up on small hand motions or changes in hand shape well. The Leap Motion Sensor on the other hand, fine-tunes hand movements which allows intricate signs to be recognized (see Figure 2); but the Leap is unfortunately restricted to hand motions and cannot pick up on changes in the body or face.

A project that used the Leap Motion Sensor for ASL recognition was a system built by Chuan, Regina and Guardino [7]. These researchers found that students learning ASL normally had to videotape themselves signing so that instructors could view and grade their accuracy and skill at a later time. Similarly, students learning ASL also had to learn from either videotaped signing tutorials or face-to-face courses. This left a great area of opportunity for an ASL recognition system that could give students instant feedback on their signing accuracy, minimizing instruction and assessment time, so Chuan, Regina and Guardino used the Leap and its ability to pick up on fingertip position, knuckle positions, palm direction and palm normal to build a system that recognizes the 26 characters of the English Alphabet.

To do so, they collected data from two faculty members, one hearing, one deaf, and used machine learning to build a system off of this data. This collected data served as a base for a four-fold cross validation. There were numerous difficulties that arose during the building process, including the similarity of the signs for certain letters, which made it difficult for Leap to distinguish between them (see Figure 1). The resulting product however was so successful that the researchers concluded the Leap Motion sensor in combination with a webcam, has the potential to change the method in which individuals learn and teach ASL. [7].

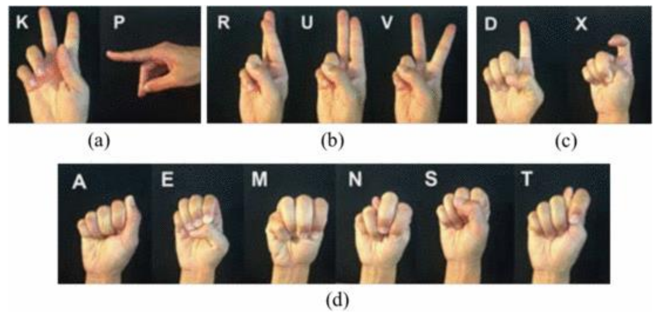

Figure 1. Similar signs that Leap Motion had the most difficulties distinguishing.

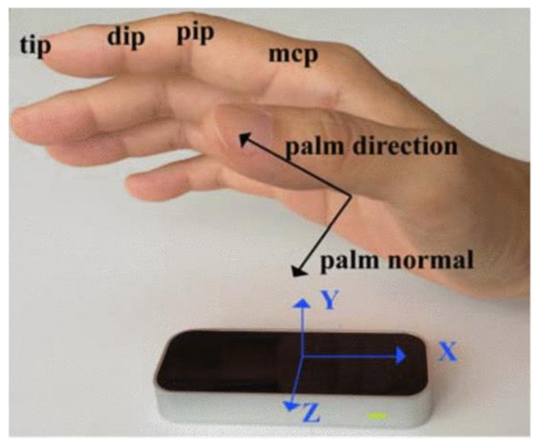

Figure 2. Information about the hand that is available using the Leap Motion.

THEORETICAL BACKGROUND

We chose to create a Tangible User Interface in this project to take advantage of the cognitive and social benefits TUI's can provide. Klemmer et al. argues that cognitive development and cognitive processes at any age are directly related to the world through gesturing, epistemic action, and thinking through prototyping [13]. From an embodied perspective, the cognitive system consists of interactions between the brain, body, and environment. In other words, humans learn from and learn with their surroundings [1]. Therefore, a successful educational tool must incorporate the user's surroundings into the learning process and Tangible User Interfaces make this possible.

Hummels also discusses the concept of a cognitive scaffold. This refers to a tool or object found in a user's environment that helps one solve problems much better than one would when using only mental abilities [9]. A commonly understood view of cognition is known as reflexive cognition--the type of cognition that one participates in when solving a math problem, brainstorming new ideas, etc. Reflexive cognition is slow and deliberate compared to experiential cognition. This cognition is utilized when one participates in a learned, skilled behavior that takes little conscious thought such as throwing a baseball or driving a car [20]. Our system aims to use the body and environmental tools and cues in order to assist in the learning process.

A paper that investigated the impact of game-based learning on information retention is “The Effectiveness of the Game-Based Learning System for the Improvement of ASL Using Kinect”. This research project divided the participants into two groups: Group A, the game-based learning group, and Group B, the traditional face-to-face learning group. Both groups took a pre-test to assess their current knowledge of the signs for the same set of vocabulary. This vocabulary consisted of animal names such as bear, lion, goat and butterfly. Then, both groups were taught the signs for these words through their respective teaching methods. After the session, both groups took a post-test identical to the pre-test to assess the information retention from their course. The results showed no significant difference between the pre-test results of the two groups. The post-test results, however, showed that Group A, the game-based learning group, scored a higher average of accurate retention. This research not only proved the significant effects of game-based learning on sign retention but also displayed the positive effects of game-based learning on engagement, enjoyment and enthusiasm during the learning process.

Games are a learning tool used to engage an audience, particularly this works well with younger children. One strength of games is the promotion of metacognition–the process in which users reflect on their own learning activity. Games provide instant feedback about a player’s process, allowing users to reflect on their previous actions and strategies. Due to the competitive nature of games, players are incentivized to examine how their performance could be improved. Metacognition is essential in increasing the depth of an individual’s learning process, as well as improving their ability to apply the learned information to different contexts [1]. Within games in general, metacognition and feedback are two very important aspects that can be critical to reaching the full potential that games offer the learning experience.

Most educational games are single player games, which has two main weaknesses: lack of diversity in the solution space and short learning period, where even if the player continues to play the game, they have already mastered the skill the game was teaching. Competitive games, such as chess, provide a much larger solution space and introduces an element of unpredictability to games that extends the learning period since players are playing against other humans and won’t be able to predict their opponent’s strategies. Playing against opponents who create new strategies to win encourages player creativity as well, as long as the game is well balanced with no dominant strategy. Multiplayer games can be utilized to increase the depth of a user’s learning.

DESIGN

From the beginning of our design process, we chose to frame our learning in a game to increase user engagement and excitement with our project. While a few different game like concepts were explored like a treasure hunt versus a maze, we used opportunities to input learning moments as a deciding factors towards final game play. For example, we knew that during the game we wanted users to go up to characters and perform certain ASL signs. This gave users a sense of conversationality, which was a learning objective of ours. Upon the correct completion of the sign, users would be given hints and directions to lead them on their journey. One of the most important factors of this initial design was the idea to integrate the signs for “walking,” “left,” and “right” into the game’s navigation system, and we ultimately chose a town setting because it provided a much richer sensory environment for the user while maintaining the exploratory facet of gameplay.

One of the first challenges of implementation was deciding whether to use the Kinect or the Leap Motion Sensor as our technological basis. While the Kinect can detect full body movements (important in the proper execution of many words in ASL), it fails to detect many fine-tuned hand motions. Additionally, the Kinect is an older technology with which a good bit of recent software is not compatible. While the Leap Motion Sensor does not have the capabilities to detect full body movements, its precision in detecting movements as well as the abundance of features that it perceives made it an appropriate choice for our project. Upon choosing the Leap, we also narrowed the game to focus on weather-related words, as many of these do not involve full-body movement.

Using Unity to build graphics and gameplay and using the Leap to detect the correct ASL signs, we were able to build a game that responds to users signs. The green color of the hands indicates that users have performed the sign correctly; this gives the users feedback on their learning process (see Figure 3). We then worked through the prototyping process, building different environments in Unity and coding the leap to recognize various ASL signs as well as integrating the signs for “walk,” “left,” and “right” into gameplay navigation. The gameplay teaches users to sign simple sentences, introducing them to conversationality. Additionally, this immersive game will excite children and build their confidence in learning American Sign Language.

Figure 3. Immediate feedback when player signs a word correctly, in this case, "rainy."

CURRENT IMPLEMENTATION

Our current implementation is built in Unity and uses the Leap Motion to detect the user's hand signs (see demo video at https://www.youtube.com/watch?v=l9C8cILWKlI). The player starts out in a town setting next to weather equipment and a news van, where the boss informs them that the weather equipment has broken down and issues the challenge: can the player go to the different neighborhoods to check the weather for their upcoming broadcast? Once the player has accepted the challenge by signing "yes", a tutorial video shows them how to sign "walk", "left", and "right" to navigate in the world, and how to engage with the other characters in the world by signing "hello" when they are close enough to start a conversation. They can access this tutorial again at any time by pushing the question mark button on the upper right hand corner of the screen.

When the player is in range of a avatar, the avatar will turn and face the player while greeting them. The player can then sign "hello" to trigger a tutorial video showing them how to sign the weather at that location, for example, "rainy outside" for the park terrain, "cold outside" for the tundra terrain, and "hot outside" for the desert terrain. Once the player has visited all three locations, they report back to the boss the phrases that they learned at each terrain (see Figure 4). Players will know they signed a word correctly when the hands turn green, giving them immediate feedback when they perform the sign correctly. The current implementation of the game can recognize "hello", "walk", "left", "right", "yes", "cold", "rainy", "hot", "outside", "weather", and "today".

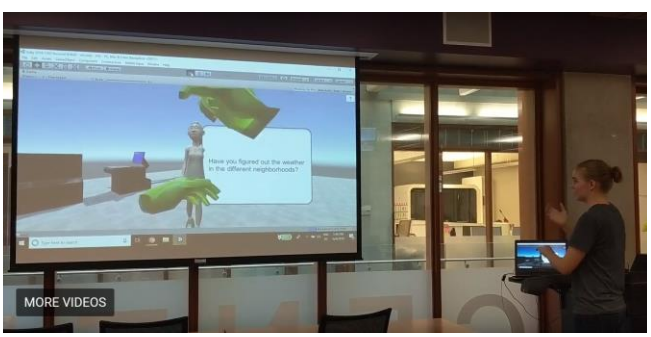

Figure 4. Reporting back to the boss by signing all the weather phrases taught in the level.

CONCLUSION

In conclusion, Sign Town effectively incorporates the engagement needs for elementary aged students while teaching ASL. Through scaffolded learning users have access to a limited set of words at any time, and as the levels progress, they gain a larger vocabulary and sentence base.

FUTURE WORK

For future iterations of the game, we would like to evaluate other technologies to determine which will be best for our long term vision. As mentioned before, the Leap Motion only detects the hands, so other technologies, such as computer vision, that could track the whole body yet still retain detailed information about the hands would be ideal. This would increase the number of signs we would be able to accurately detect, and if the technology allows, could also let us add a multiplayer component to the game for classroom use, where the teacher could lead the students through the game or students could explore the level together. The setup, where the Leap is connected to a laptop via a USB cable and the laptop can then be connected to a projector or display, is simple and should allow for social scalability especially if additional Leap Motion sensors could be added (see Figure 4).

We would also add more levels to increase the complexities of words and sentences taught. Each level could be a different theme, such as animals, or color, or sports. Ideally, we would also use machine learning to recognize words instead of hardcoding the signs, and have the avatars sign the tutorial words and wait for the player to correctly sign the word before moving on. Gameplay would flow smoother, and the tutorial would be more interactive and allow for time for the user to get feedback before moving on to the next word.

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