

# A Gesture-Based American Sign Language Game for Deaf Children

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## ABSTRACT

We present a system designed to facilitate language development in deaf children. The children interact with a computer game using American Sign Language (ASL). The system consists of three parts: an ASL (gesture) recognition engine; an interactive, game-based interface; and an evaluation system. Using interactive, user-centered design and the results of two Wizard-of-Oz studies at *Atlanta Area School for the Deaf*, we present some unique insights into the spatial organization of interfaces for deaf children.

## Author Keywords

Deaf; children; ASL; design; Wizard-of-Oz method; computer games; computer aided language learning

## ACM Classification Keywords

H.5.2 [Information interfaces and presentation]: User Interface - User-centered Design; K.8.0 [Personal Computing]: Games

## INTRODUCTION

### Motivation

Ninety percent of deaf children are born to hearing parents who do not know sign language [3]. Often these children's only exposure to language is from signing at school. Early childhood is a critical period for language acquisition, and exposure to language is key for linguistic development [7,8].

By twenty-four months of age, hearing children learning a spoken language are combining words in spoken communication [11]. By age eighteen months, deaf children of deaf parents are combining signs to communicate. A third group, deaf children of hearing parents, develop language at a much slower pace, attributable to lack of exposure to language and incomplete language models [5,9]. The short term memory for sequential linguistic information in deaf children of hearing parents also appears limited compared

to that of hearing subjects [1,4]. This limited memory processing ability may also be responsible for the slower acquisition of language due to an inability to receive and process longer utterances efficiently. Our goal was to expose the children not only to individual vocabulary signs, but also to encourage them to formulate those signs into longer concepts and phrases.

## Proposed Solution

Our project involves the development of an American Sign Language (ASL) game which uses gesture recognition technology to develop ASL skills in young children. The system is an interactive game with tutoring video (demonstrating the correct signs), live video (providing input to the gesture recognition system and feedback to the child via the interface), and an animated character executing the child's instructions. The system concentrates on the practice and correct repetition of ASL phrases and allows the child to communicate with the computer via ASL. We target children attending the Atlanta Area School for the Deaf (AASD), ages 6–8, who are behind in their language development.



**Figure 1. Screenshot of Game Interface. a) Tutor Video b) Live Camera Feed c) Attention Button d) Animated Character and Environment e) Action Buttons**

The game involves Iris the cat who can interact with her environment in a number of ways based on what the child signs to her. With the assistance of educators at AASD, we developed a list of eight age-appropriate ASL phrases (see Table 1).

When beginning the game, Iris is asleep. The child can press an Action Button (Fig. 1e) and watch a short video clip showing the correct ASL command in the Tutor Window (Fig. 1a). Next, the child clicks on the Attention Button (Fig. 1c), and Iris wakes up. The child then signs the command to Iris. A live video feed allows the child to see herself (Fig. 1b). If the phrase is correct, Iris carries out the command or answers the child's question with a pictorial thought bubble in the window (Fig. 1d). If the child does not sign correctly, a thought bubble with a question mark appears above Iris's head.

Eventually, a gesture recognition system will control the computer's response to the child's signing. However, while the gesture recognition system is under development, we began the initial game design via Wizard of Oz (WOz) methods. The goal of this phase of the project was to design a prototype for the game which the children would find engaging and interesting enough to practice their signing. By observing how the children use the system, we will enhance usability and enjoyment.

### Task Development and Method

Due to a very limited subject population, it was important to remove as many errors from the interface and interaction sequence as possible before attempting to run a longitudinal study to evaluate language acquisition using the game. We decided to use children slightly older than our targeted age (ages 9–11) for short pilot studies because they were capable of giving us more feedback about the interface. We tested student in groups of 2 or 3, making subtle changes based on the previous groups' opinions and feedback.

In addition to giving us crucial user feedback and allowing us to improve our design, the WOz study provided an ideal method to gather data for our gesture recognition system. This diverse sample set allows for testing and development of our gesture recognition software with a variety of signers, signing techniques, skin tones, and physical attributes. This data set is invaluable for training of the mathematical models and performance testing of the gesture recognition system.

Glossed ASL	English Translation
q(YOU LIKE MOUSE)	Do you like mice?
q(YOU HUNGRY NOW)	Are you hungry now?
YOU GO PLAY BALLOON	Go play with the balloon.
IRIS GO-SLEEP NOW	Go to sleep now, Iris.
YOU GO CATCH BUTTERFLY	Go catch the butterfly.
whq(WHO BEST FRIEND WHO)	Who is your best friend?
LOOK-THERE IRIS MOUSE OVER-THERE	Look, Iris! A mouse, over there!
YOU MAKE FLOWERS GROW GO-ON	Go make the flowers grow.

**Table 1. Glossed ASL Phrases and English Translations**

### WIZARD OF OZ EXPERIMENTS

To date, we have performed two pilot studies with five participants at AASD.

Subject & Gender	Playing Time (min:sec)	Number Attempts	Self-Ended?
1 - F	14:06	18	yes
2 - M	4:55	11	yes
3 - F	9:42	21	yes
4 - M	18:10	50	no
5 - M	12:22	28	no

**Table 2. Subjects' Pilot Test Data.**

The system is equipped with a desktop computer, two monitors, a camera, and a digital video (DV) recording device. For input, the mouse from the computer is given to the child while the keyboard is given to the wizard to control the interface actions. This configuration allows for the use of a single desktop machine with two monitors, thus eliminating the need for networking and synchronization across computers. The DV device records the interface as it is shown to both the participant and the wizard. Additionally the computer creates a log file of concrete events (mouse clicks, button presses, key clicks, wizard actions, etc.).

### First Pilot Test

The first pilot test of our system had three concrete goals. First, we wanted to evaluate whether the game was engaging to the children. Second, we needed to confirm the interchangeability of interpreters and ascertain whether the interpreters were consistent in their evaluation of the children's signing. Third, we were concerned with the "push-to-sign" mechanism and wanted to confirm that the children would remember to press the button before and after they signed.

The test consisted of two girls and one boy from the same class. All children watched a brief video in ASL telling them how to play the game. We informed all participants they could stop playing the game whenever they wanted. Our facilitator demonstrated the game. The children then attempted to play the game on their own. Table 2 (subjects 1–3) shows the amount of time the children spent playing, the total number of attempted phrases, and whether they stopped playing of their own accord or were asked to stop.

### Apparatus and Conditions

An ASL interpreter from AASD evaluated the child's signs from behind a partition, and the wizard keyed the appropriate response. After finishing the test, we asked participants several questions related to preference, ease of use, and satisfaction to evaluate the game and test setting.

### Observations and Conclusions

We observed that the interpreters had very different criteria for what they considered "correct" signing. They often based their assessment on their personal knowledge of the child's ASL skills. We considered this unacceptable and changed the experimental setup for the next pilot test.

The push-to-sign mechanism was not a problem for the children. After having it demonstrated once or twice, they rarely forgot to use it.

Each child played until he/she indicated that he/she was finished. Our goal was to engage the child for 20 minutes, yet none of the children met that goal. We decided the game required a smoother flow to encourage the children to attempt the phrases again after an incorrect response.

### Second Pilot Test

Our previous work on gesture recognition [2] had determined that a combination of sensors provided better accuracy than only a computer vision approach. Thus, we wanted to perform the tests with children wearing small colored gloves (to enhance the computer vision algorithms) with small wireless accelerometers mounted on the wrists. We were unsure how the children would react to the gloves and if the gloves would impair their signing.

To stimulate longer interactions, we changed the flow of the game slightly. Upon receiving the indication that their signing was not correct, we automatically played a video clip of the phrase with the explicit instruction, such as, “You tell Iris, ‘you go play balloon.’” Previously, when Iris did not understand a phrase, the child had to press the same action button to see the video again.

For this test, our facilitator from AASD acted as the only interpreter, and eliminated the variability of interpretation. We also encouraged him to be consistent and strict for each participant. The facilitator watched the live video and cued the wizard to have Iris respond or look puzzled.

The subjects this time were two boys from the same class as the previous subjects. (Participants 4–5 in Table 2.)

### Apparatus and Conditions

During the prior test, the children sat behind a child-sized desk. Many signs were blocked as the children’s hands tended to slip behind the desk. We changed the arrangement of the furniture and moved the desk to the participant’s right side (both children were right handed), leaving the front camera view unobstructed.

### Conclusions and Observations

Again, Table 2 gives the times the children spent playing the game. However, both of these children played until we stopped them (due to class time limitations) and appeared highly engaged in the game, offering commentary such as, “That’s weird!” when the system did not recognize what they thought they had signed correctly.

One boy indicated that the accelerometers and gloves were “fine.” The other boy indicated they bothered him a “little bit,” but he would still use them if they were necessary to play the game.

## OBSERVATIONS AND CONCLUSIONS

These experiments were not meant to yield statistical results, and we chose not to concentrate on the accuracy of the children’s signing due to the wide variability of interpreters and the confounding issues of ASL’s spatial grammar. Instead

we report several interesting observations that will heavily influence our future work.

### Spatial Aspects of ASL

ASL is a spatial language with rich directional expression. In ASL each signer has a “signing space” which is maintained in front of the signer. By setting up subsections of the signing space and indexing the subsections (by referencing them in conversation), signers indicate interactions between concepts, people, times, etc. For a full discussion of the spatial construction of ASL, see [6] (Ch. 2–3) and [10].

For example, verbs can be directional and imply subject and object from the way they move through space. For example in the phrase “Bob, tell me the answer,” the sign for ‘tell’ moves from Bob to me. If instead the phrase was “I’ll tell you the answer” the sign moves from me to Bob. During the second test, we used phrases such as, “You tell Iris, ‘go play balloon.’” We thought the children would understand that the imperative “you tell Iris” was directed at them and the second half (‘go play balloon’) would be the phrase needed to activate Iris. However, we discovered that both children included the directive ‘you tell Iris.’ After reviewing the video clips that the children were shown, both we and the ASL educators at AASD believe the interface layout and expression of the signing video were not spatially compatible.

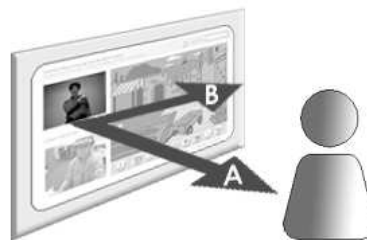


Figure 2. Interface and Tutor’s Signing Space

We believe the children were treating the interface as an ASL construct rather than a 2D interface. Thus, when the tutor signs “you tell Iris,” she should sign directly to the child (Figure 2a). When signing the command “go play balloon” she should turn 90 degrees and sign toward the animated cat (Figure 2b). Thus, she would maintain proper ASL spatial grammar. Since the video was shot without this concern, the child was confused.

### Effect of Repetitive Tutoring

Anecdotally, some teachers at AASD report that many of the children have difficulty generating complete sentences in sign. Instead, the children rely on context to fill in the blanks for them when communicating with others. For example, they may sign “balloon”, instead of the more complete request, “Can I have the balloon?” When creating this game, a primary goal was to motivate the students to practice generating complete sentences for clearer communication and stronger language skills.

In our experiments, children sometimes violated proper ASL grammar or omitted several vocabulary words while signing the phrases. For example, the phrase “you go play balloon” was sometimes shortened to “you balloon,” and the wizard evaluated the partial phrase as incorrect. However, when Iris did not understand, the children tended to watch the tutoring video again. They then tried the phrase again and corrected their sign. We observed that the stricter evaluation criterion led to more attempts by the children, and they signed more clearly and distinctly with each attempt. Unlike a teacher who can easily guess unclear signs, the animated character and computer didn’t allow the child to insert or delete vocabulary from the phrases. This led the children to practice the process of problem solving through multiple attempts instead of reverting to their previous linguistic habits. They tried to “think” and came to “know” what the computer would not accept with their signing though various trials. This is a good starting point for motivating and accelerating proper language skills.

A longitudinal study will need to be conducted to measure whether language improvement occurs or if the children are merely duplicating what they see.

### Users’ Preferences

The phrases in the game contain actions which direct the cat to interact with a butterfly, a flower, mice, etc. In general the contents of the game seemed to engage the girls more than the boys. Girls tended to play again even after finishing all the actions with clear signs. Boys indicated they would prefer races or more competitive games. Developing a gender neutral narrative will provide greater motivation to children and is key to our next design iteration.

Among the eight phrases, three are questions whose answers appear in Iris’s pictorial thought bubble, and five are commands directing Iris to a particular action. Children preferred animations with kinetic action rather than static thought bubbles. This has led to a revision of the phrases for the next pilot tests.

### FUTURE WORK

We will continue to use small pilot studies with older, articulate students to refine our interface and game design. We will then undertake a larger WOz study with children ages 6–8. The children will play two times a week for four weeks to determine how their language skills improve. Both before and after the experiments, the teachers of the participants will be asked to answer surveys on the children’s language skills. These surveys will be used to evaluate the system.

Additionally, camera feeds and log data can be used to compile a “workbook” that is viewable in chronological format. The workbook will be designed to help teachers target problem areas for an entire class or an individual student. This evaluation package will enable our system to function as a complete educational tool.

To achieve our goal of longer interaction time with the game, we decided that the game needed a more elaborate structure and interactional goals. We believe incorporating various rewards (such as moving on to a higher level or achieving a higher score) will allow the user to have a richer experience and may enhance the user’s motivation. By making each task or level progressively more difficult, we expect that the game will be more challenging to students and help them to develop better signing skills and linguistic memory.

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