Augmenting Communication Between Hearing Parents and Deaf Children

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ABSTRACT

Deaf infants born to hearing parents are at risk of language deprivation, which may lead to life-long impact on linguistic, cognitive and socio-emotional development. It remains demanding for hearing parents to provide meaningful and linguistic-rich interaction with their deaf and hard of hearing (DHH) children, due to lack of sign language fluency and insufficient communication strategies. In this study, we present a proof-of-concept visual augmentation prototype utilizing the Augmented Reality (AR) lamp metaphor that aims to support context-aware and non-intrusive parent-child interaction using American Sign Language (ASL), with adaptation to joint-attention strategies that match with the child's communication modality. The proposed prototype enables future studies to collect in-depth design critiques and preliminary usability evaluation from domain experts, novice ASL learners, and hearing parents with DHH children.

Index Terms: H.5.1 [Multimedia Information Systems]: Artificial, augmented, virtual realities; H.5.2 [Use Interfaces]: Prototyping

1 INTRODUCTION

Lack of early language access has critical implications on children's cognitive and psycho-social development. A prevalence of negative life outcomes, such as low literacy rates, diminished career and educational opportunities, and feelings of isolation, are often experienced by the deaf population as a result of early language deprivation [8, 11]. Since above 90% of deaf children are born to hearing parents who are often non-fluent in sign language, delayed exposure to an accessible language becomes a common challenge [7], thus, resulting in far-reaching consequences in life outcomes for the deaf and hard of hearing (DHH). For this reason, supporting parental communication to ensure a foundational natural language that is accessible to the DHH child becomes of paramount importance.

There are two disadvantages that hearing parents face when engaging in linguistic interactions with their deaf infant. First, the infant's time-sensitive language acquisition window makes it difficult for the hearing parent to learn American Sign Language (ASL) and deliver it in a timely manner. While infants rapidly acquire language within the first few years of life, it becomes strenuous for the parent to learn a second language given limited time and resources. Second, the different communication modalities between the hearing parent and their deaf infant engenders insufficient communication strategies for the child's linguistic uptake. For example, hearing parents are often unsuccessful in engaging in joint attention episodes with their deaf child [2] since adapting visually sensitive communicative behaviors does not come naturally to someone accustomed to communicating via the auditory modality. With these disadvantages in mind, we developed the following research questions to guide us in improving parental communication: How to develop assistive technologies that support hearing parents to 1) carry out **just-in-time** and **situation-aware** ASL to their DHH child? (2) adapt to sufficient **joint attention strategies** for linguistic uptake for their DHH child? (3) How to develop assistive technologies that support **non-intrusive** face-to-face interaction?

Informed by studies done in sign language acquisition and joint attention, we propose a proof-of-concept prototype that uses projection-based augmentation to support hearing parent-deaf child linguistic interaction through real-time, non-intrusive, and context-aware ASL labeling. Our prototype serves to improve the parent's ASL fluency by projecting ASL vocabulary videos next to child's object of visual interest and enhance parent's visual communicative behaviors by using this ASL labeling as a visual feedback cue on child's eye gaze. The system targets infants of 6 to 18 months of age, which is when infants are first beginning to develop social communicative behaviors that aid in vocabulary acquisition [5]. Furthermore, our goal is to facilitate successful moments of joint attention, while also providing the hearing parent ASL learning opportunities. We will conduct a survey study to collect design critiques and preliminary usability feedback, and use the findings to iterate the system for future studies to evaluate its effectiveness.

2 RELATED WORK

2.1 Sign Language Acquisition

Research in sign language acquisition helps us to better understand how to effectively support the hearing parent's ability to provide sign language input for their deaf infant. It is important to note that while sign language differs from spoken language, it is a complete natural language with similar linguistic features characteristic with spoken languages, such as lexicon, grammar, and phonemes [17]. Because of the similarity of structures between ASL and spoken languages, there is no delay in acquisition of language milestones (including vocabulary development) between infants exposed solely to sign language with infants exposed solely to spoken language [2, 14]. Given this, we decided that our system should use vocabulary-based augmentation to deliver sign language instruction to the parent as they interact with their DHH child.

One concern we want to emphasize is the effectiveness in non-native ASL being delivered to the deaf infant. Hearing parents of DHH children often learn ASL along with their child, and thus are not fluent signers of the language. However, while late language learners are bound to make errors in their language production, children receiving this input are still able to learn from this. They are able to extract regularities in the input and find meaningful structures within the language, and ultimately not produce the same errors [9, 20]. Thus, even when the hearing parent is beginning to communicate in ASL, we can still expect the deaf infant to benefit from this inconsistent language input.

2.2 Joint Attention and Language Development

Several studies have examined the importance of social interaction in language acquisition, specifically the communicative skills and vocabulary development that stems from joint attention episodes between parent and child. Joint attention refers to the states when children and adults attend to the same object in the world [5]. For the typical hearing infant, joint attention facilitates word-learning

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as it promotes relating objects in the environment with object labels a caregiver delivers simultaneously. Indeed, the time spent in joint attention between caregivers and children is a positive predictor of language development [5, 23]. However, a DHH infant can only perceive joint attention episodes in a unimodal (visual) system.

Hearing parents of deaf children must adapt to their joint attention strategies from relying on both visual and auditory cues, to solely visual cues. They must learn to utilize the critical modality available to their child to provide linguistic input [2]. In contrast, deaf children of deaf parents, through repeated interactions, learn that gazing towards the parent is linked with linguistic input [2]. This is because deaf parents engage in communication strategies tailored towards their child's perception abilities (i.e., using touch), thus supporting joint attention [2]. Through this socialization, deaf infants are able to acquire the visual-perceptual ability that is involved in coordinating attention between parental linguistic input and non-linguistic context in the physical environment. If this sophisticated gaze behavior is not supported by parent-child interactions, there is a risk in delaying the development of cognitive processes, including that of language acquisition [18]. It is heavily dependent on the parent to be visually-oriented in their communicative interactions with their deaf infants, which is a skill we aim to improve in hearing parents through our design approach, specifically by eliciting attention-awareness through visual feedback cues.

2.3 Current Interactive Technologies

There is a wide range of interactive technologies proposed to support ASL and language access to the DHH population. The emergence of AR technologies, especially using head mounted displays (HMD), and advances of artificial intelligence technologies [6] have shown promising advances in providing ASL interpretation and translation in various situations such as TV reviewing [25], science learning [14], and conversation [16], as well as supporting second language learning by associating language inputs directly with the real-world object [12]. Limited access, ergonomic factors, and social-cultural acceptance [6, 13], however, currently constrain AR HMD in supporting young children and face-to-face interaction. In addition to AR, previous research has proposed to use text-based ASL search on mobile phones to facilitate ASL learning for deaf children and their parents [15]. Avatar is a common media for automated generation of ASL [1, 10]. A recent study uses a social robot and virtual avatar to provide increasing language exposure for deaf infants, through directing attention to ASL nursery rhymes [19]. Informed by these studies, our system design focuses on providing language exposure to the deaf infant through augmenting the parent's real-time, in-context ASL.

3 System Design Rationale

Our prototype design aims to improve the hearing parent's ASL fluency by facilitating opportunities for real-time vocabulary signing during face-to-face joint play scenarios. In addition, our design approach encourages the development of visually-sensitive communicative strategies by providing non-intrusive attention-awareness. For the first goal, to increment the parent's ASL knowledge, and thus fluency, the challenge lies in linking objects found in the physical environment with respective ASL label. To mediate this obstacle, we chose visual augmentation due its shown enhancements in language learning. For example, AR labeling has been previously successful in secondary language learning by allowing users to reference augmented foreign-language labels on objects found in their real-world environment. This resulted in better recall of newly acquired vocabulary and enhanced the learning environment for adult learners [12]. For this reason, we chose visual augmentation of ASL labels to aid the parent in associating newly learned ASL words with the current physical environment. The ASL labels will be in the form of on-demand ASL vocabulary videos that will be projected on a table near the target objects towards the parents side. The location design of the ASL label prevents additional eye fixation beyond the object and interlocutor and thus prevents interference in episodes of coordinated joint attention between communication partners.

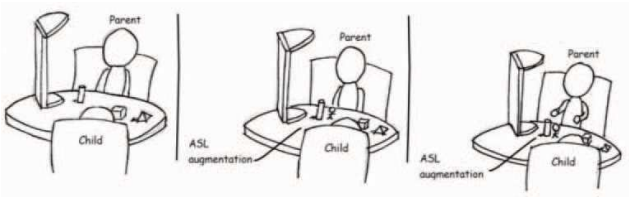

Figure 1: Storyboard illustrating parent signing next to the object cylinder after ASL augmentation is projected.

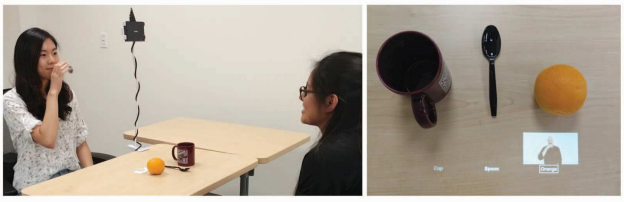

Figure 2: Projection of the words cup, spoon, and orange

Given that our system serves in real-time, face-to-face play scenarios, the form factor had to be hands-free to ease the parent's sign language production and prevent occlusion of their facial expressions, a critical factor in non-intrusive interaction and understanding sign language. Inspired from previous work done in portable projection-based AR systems [17], we decided to utilize lamp augmentation in play scenarios between parent and child.

For the second goal, high-level awareness of a child's visual gaze becomes necessary in adapting to visually-oriented communicative interactions, contributing to episodes of joint attention, and hence successful communicative interactions between parent and child [22]. Simple communication systems have been previously explored to output information to users, requiring low cognitive effort. For example, visual signals were used to communicate to runners of their supporters' cheers with minimal to almost no interference with their focus [26]. In addition, when it came to delivering sound awareness, majority of DHH users preferred both visual and haptic feedback cues [6]. Given this, in our investigation, we explore using a visual indicator to deliver feedback to the parent of their child's visual attention. The system will begin playing the ASL video next to the object the child is gazing at, serving as an on-demand ASL vocabulary cue (see Fig.2). We expect this visual feedback cue to provide a low mental load for the parent in maintaining attention-awareness. In addition, in our future work, we want to explore the potential advantages of haptic feedback in further reducing mental load for visual processing.

4 System Implementation

To evaluate the effectiveness of sign language learning using projected ASL videos, we developed a low-fidelity prototype of the AR Lamp. The prototype employs a Wizard-of-Oz evaluation and is designed to demonstrate the utility of having ASL videos as a visual cue for the child's attention.

The setup consists of a portable projector (Miroir Micro Projector M45), a gooseneck clamp holder, and a laptop computer hosting a user interface with the projection contents (see Fig.2). The web-based interface uses JavaScript, HTML, CSS, and the YouTube IFrame Player API and allows an experimenter to select and display the ASL video that corresponds to the object that the child is visually

attending to. Referencing the MacArthur-Bates Communicative Development Inventory [3] and *Dr. Bill's Baby Signs* [24], we curated a small sample of videos of the most common ASL signs that infants first learn and that can be used in daily activities. We are currently working on the object recognition and gaze-tracking features; for the former, we plan to utilize state-of-the-art object detection libraries (e.g. OpenCV and TensorFlow) and computer vision algorithms. In addition, plans on using publicly available sign language video corpora [4] will help curate ASL labels that are typical of real-life signs.

5 Informal Feedback

Domain experts gave us generally positive initial feedback on our design. However, several technical challenges regarding infant behavior need addressing. For example, there were concerns in tracking a young infants visual focus, which is characterized by frequent gaze shifts [2]. In addition, confining the system to word-only translations inhibits social-emotional expression between parent and child. Finally, comments on affordability, portability, and parental acceptance were also mentioned.

6 Future Work and Conclusion

This design approach explores a potential technology that uses attention-awareness and ASL instruction to improve parental communication through DHH infant language exposure. For future work, we are aiming to conduct a formative study to solicit feedback on our proof-of-concept prototype. Firstly, we would like to pilot a survey to assess the potential of our system design, in which we will be able to gather parental interest given their specific demographic information and form factor preferences. In addition, we will use paradigms found in language acquisition literature (e.g artificial language learning paradigm [21]) to guide our evaluation methods in testing our systems efficacy in the learning outcomes of users.

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