# Teaching ASL Signs using Signing Avatars and Immersive Learning in Virtual Reality

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## ABSTRACT

We present here a new system, in which signing avatars (computer-animated virtual humans built from motion capture recordings) teach introductory American Sign Language (ASL) in an immersive virtual environment. The system is called Signing Avatars & Immersive Learning (SAIL). The significant contributions of this work are 1) the use of signing avatars, built from state-of-the-art motion capture recordings of a native signer; 2) the integration with LEAP gesture tracking hardware, allowing the user to see his or her own movements within the virtual environment; 3) the development of appropriate introductory ASL vocabulary, delivered in semi-interactive lessons; and 4) the 3D environment in which a user accesses the system.

## CCS CONCEPTS

**• Human-centered computing**; **• Virtual reality;**; **• Social and professional topics**; **• People with disabilities;**; **• Software and its engineering**; **• Virtual worlds training simulations**;

## KEYWORDS

sign language, virtual humans, ASL, virtual reality

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## 1 INTRODUCTION

There is a need for improved tools to allow remote learning of American Sign Language (ASL). Learning ASL is not simply an enjoyable pastime, but is a skill which holds important health and developmental benefits. For hearing parents of deaf infants, learning ASL may be critically important, since exposing deaf children to sign language leads to better outcomes in English literacy and spoken language compared to deaf children without access to a signed language [1-4]. Using a high-quality remote learning system in virtual reality to provide an immersive ASL experience to hearing parents of deaf children could help provide those children exposure to a signed language early in life. There is a great deal of interest in sign-related technologies such as signing avatars, automatic sign translation, and sign recognition [5]. We present here our progress toward creating the first ASL instructional system in immersive virtual reality, Signing Avatars & Immersive Learning (SAIL).

### 1.1 Signing Avatars & Virtual Reality

Signing avatars have the potential to be a crucial source of natural language and accessible information for the signing deaf community [6-10]. There are many compelling possibilities for signing avatars, however creating high-quality avatars requires significant investments of time and money, and is a challenging feat of engineering [11]. Creating a signing avatar from motion capture recordings of native signers has the potential to produce more naturalistic avatars compared to those which are created from computer models. However, avatars built from motion capture require a great deal more labor and offer fewer options for automation or iterative generation of new content compared to avatars created using computed algorithms.

Sign language instruction is well-suited to VR because of the potential for spatially immersive and embodied experiences, which can facilitate learning. To date, efforts to teach sign language in virtual reality have been limited. A number of research projects have explored the possibility of teaching ASL in augmented reality, with sign language content overlaid upon a view of the real world [12-14] but there are no publicly available sign language learning experiences that exist in an immersive virtual reality space.

## 2 THE SAIL SYSTEM

SAIL incorporates principles of embodied learning. Embodied learning involves the learner's own sensory and/or motor systems. Research shows that hands-on experience with content increases the involvement of the brain's sensorimotor cortex during subsequent engagement with the content [15, 16]. By increasing one's somatosensory and motor involvement during learning, better learning outcomes are achieved [17-19].

It is thought that the success of embodied learning is dependent upon three factors: 1) amount of sensorimotor engagement; 2) congruence between action and concepts to be learned; and 3) degree of immersion experienced by the user [20]. The SAIL system fits the three described factors in the following ways: 1) the user physically produces ASL signs, engaging the sensorimotor system; 2) the actions (signs) have perfect correspondence to the concepts to be learned; 3) SAIL uses an immersive VR environment. With this work we seek to harness the interactive aspects of VR to allow for three-dimensional learning of ASL content. Learning from a 3D avatar is key since sign language uses three-dimensional space to represent linguistic content [21, 22]. Thus, ASL is an excellent candidate for virtual reality instruction.

In order to take advantage of the rich possibilities afforded by virtual reality for learning sign language, our majority-deaf team aimed to create a virtual environment which would give users a semi-interactive, realistic, and pleasant ASL learning experience. In SAIL, users learn ASL from a signing teacher avatar in a VR landscape that is accessed via head-mounted goggles. We developed a high-quality signing avatar from motion capture recordings of a native deaf signer. The avatar serves as the Teacher within the 3D environment. SAIL is built on Unity 3D, to program interactive learning sequences. A gesture tracking system (LEAP Motion; LEAP Motion, Inc., San Francisco, CA) is connected to the VR headset, so users are able to see digital representations of their own hands from a first-person perspective.

### 2.1 Building Content

The ASL lessons include food, everyday items, and basic actions, including a variety of palm orientations, handshapes, locations, and movements. For this initial version of SAIL, we focused on teaching individual ASL signs, as grammar and other crucial aspects of ASL constitute a more complex challenge for VR instruction.

With the placement of LEAP's sensor bar on the front of head-mounted display goggles, the LEAP sensor was unable to capture and process body-anchored ASL signs which require touching a specific part of the body (e.g., CAT, which touches the cheek). Thus, we only included signs which occur in the "signing space" in front of the signer's body. We also encountered problems with signs where a body part occluded another body part, like two-handed signs where both hands overlap (e.g., TRAFFIC). This limitation poses a significant limitation on the use of head-mounted displays for ASL instruction. While the user's ability to see the Teacher avatar produce the sign is not affected, the inability of the user to see their own hands produce the sign may limit the effectiveness of the system because these types of signs make up a significant portion of the ASL lexicon. For this version of SAIL, we assembled a list of 30 target signs which could be well-tracked by the LEAP motion sensor.

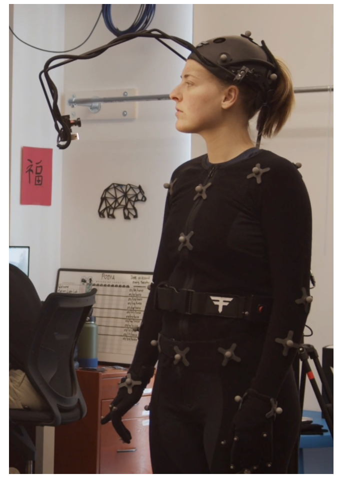

**Figure 1: The signing model prepares to produce signed content during motion capture recording. The custom-built Faceware rig extends in front of and above her face and allows space for the hands to move near the head.**

### 2.2 Motion Capture Recording

We recorded the lessons in a motion capture studio that has been developed to optimize recording of ASL. These recordings serve as the basis for animation of the signing avatars. A 16-camera Vicon system (Vicon Industries, Inc., Hauppauge, NY) was used for motion capture recording. Markers were placed on 123 locations on the signer's body, with labeling done in Vicon Blade.

Vicon Shogun 1.3 allowed for improved motion capture recording of the body, hands, and fingers. We also incorporated a custom-built Faceware Pro HD Mark 3.2 Headcam (Faceware, Austin, TX) facial capture rig, allowing for high-fidelity capture of facial expressions. The custom-built hardware used a support arm which extends high over the front of the users' face, creating space for the signer to produce signs in locations near the head and face, in contrast to the typical hardware in which the arm extends straight out from the side of the face precluding hand movement in front of the face (Figure 1). One native deaf signer acted as the model for the motion capture recording session.

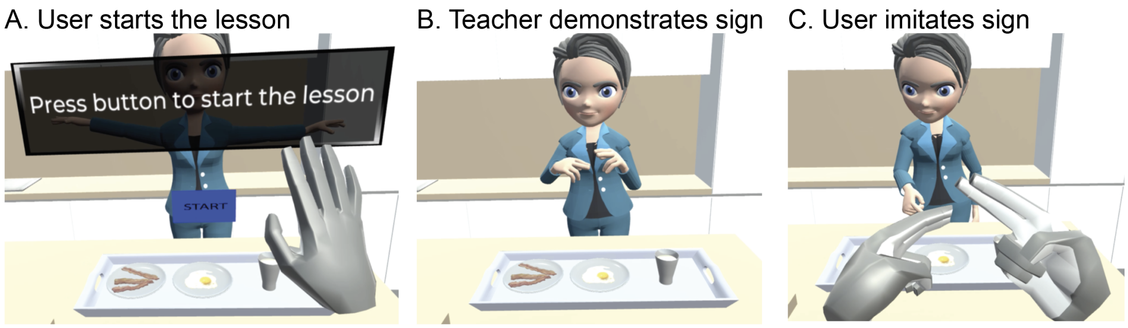


**Figure 2: The user's view inside SAIL. A) Instructions and button accessed via LEAP gesture recognition; B) the Teacher demonstrates a sign; C) the User sees their own hands as they imitate the sign.**

### 2.3 Avatar Design

A number of design considerations shaped the design of our avatar. 1) The Teacher avatar should produce fluid movements that resemble native ASL signers' movements. 2) The avatar should display the natural facial expressions critical to correct ASL grammar, again. 3) The avatar should be aesthetically pleasing, appearing humanoid, but not so human-like as to elicit uncanny feelings [23-25]. 4) The avatar should present as an "ideal" ASL teacher—knowledgeable, competent, kind, and professional. 5) The design should emphasize the avatar's hands and eyes, to clearly convey ASL.

### 2.4 System Design

Input from ASL educators, deaf ASL users, hearing ASL students, human-computer interaction engineers and digital designers was sought and used to direct the system design. This input was gathered via internal meetings with consultants and collaborators, demonstrations at professional meetings, and leadership from Deaf team members throughout development. SAIL is built on Unity 3D (Unity Technologies, San Francisco, CA) and is accessed on the Oculus Rift S (Oculus VR, Menlo Park, CA). The SAIL system uses LEAP sensor mounted to the front of the Oculus goggles to represent a user's own hands as they learn ASL signs from the avatar. This allows users to access visual feedback of their own actions during the learning process, which may be important for learning manual actions [26]. Menu buttons are shown as floating buttons which are pressed by extending the hand and using the LEAP hand movement sensor to trigger the button press (Figure 2). The Teacher is shown in an indoor environment rendered in Unity3D. The user's view is mirrored on a separate display so that experimenters may view it simultaneously.

## 3 USABILITY TESTING

A preliminary study was conducted, focused on the user interface and specific design factors (e.g., speed of signing). We recruited a small sample of participants from the local community. Six hearing, English-speaking individuals (5 males; ages 25 – 34, M = 27.5) with little-to-no prior ASL knowledge participated in the study. All participants provided informed consent and were compensated for their time.

Participants completed one Lesson of SAIL six times in total. They were asked to provide their impressions of the environment, the Teacher, and the pace of the signed content. All six participants responded "yes" to the question "would you be interested in using VR to learn ASL based on your use of SAIL?". In response to open-ended questioning, ten comments were made about the timing of the signs, most of which recommended more time between the signs or more time for the user to produce their sign. In response to this feedback, as well as related recent work using the same avatar [Anonymous, under revision], we changed the avatar's signing speed to 65% of the original speed for future iterations of SAIL.

Users expressed interest in corrective feedback, which is an aspect of ASL instruction which must be further pursued in the realm of virtual/augmented reality instructional development. Four participants mentioned the notion of corrective feedback, such as a desire for "more interaction, more back-and-forth with the instructor", "feedback from the teacher", "error identification", and noting that the "lack of error monitoring makes it less natural/believable".

## 4 REFLECTIONS AND CONCLUSION

Preliminary user research suggests that immersive virtual reality is an appealing and engaging tool for users, given the feedback from our test participants, as well as informal sessions with colleagues and students. Without fail, users react positively to the overall experience, and report positive feedback about the potential for learning ASL from an avatar in immersive virtual reality. One challenge that we encountered during the development process was the difficulty of representing body-anchored signs in virtual reality. While this constraint allowed us to more carefully develop the first iteration of the SAIL system, including only neutral-space signs would place undue limitations on future iterations of this work. Future work on SAIL will include developing a feedback (e.g., error monitoring) system to provide corrective instruction on signs regardless of their location, in line with much of the user feedback expressing a desire for this feature.

Our development of SAIL contributes to a new generation of ASL instruction methods. We have created a proof-of-concept VR ASL instructional system which allows users to receive ASL content in three-dimensional space, with the fluid, natural movements of a fluent signer. The highly-spatial nature of ASL is well-suited to three-dimensional virtual reality environments, and the system we present here motivates future work developing sign language instructional content across a variety of virtual or augmented reality platforms.

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## REFERENCES

[1] S. R. Easterbrooks and S. Baker, Language learning in children who are deaf and hard of hearing: Multiple pathways. Boston, MA: Allyn & Bacon, 2002.
[2] C. Padden and C. Ramsey, "Reading ability in signing deaf children," Topics in Language Disorders, vol. 18, no. 4, pp. 30-46, 1998.
[3] C. Padden and C. Ramsey, "American Sign Language and reading ability in deaf children," in Language acquisition by eye, C. Chamberlain, J. Morford, and R. Mayberry, Eds. New York: Psychology Press, pp. 65-89, 2000.
[4] P. M. Prinz and M. Strong, "ASL proficiency and English literacy within a bilingual deaf education model of instruction," Topics in Language Disorders, vol. 18, no. 4, pp. 47-60, 1998.
[5] D. Bragg *et al.*, "Sign Language Recognition, Generation, and Translation," in ASSETS '19: Proceedings of the 21st International ACM SIGACCESS Conference on Computers and Accessibility, Pittsburgh, PA, October 28-30, 2019. doi: 10.1145/3308561.3353774.
[6] N. Adamo-Villani, J. Lestina, and S. Anasingaraju, "Does Character's Visual Style Affect Viewer's Perception of Signing Avatars?," in E-Learning, E-Education, and Online Training, vol. 160. Cham: Springer, Cham, 2015, pp. 1-8.
[7] Y. Bouzid, M. A. Khenissi, and M. Jemni, "The Effect of Avatar Technology on Sign Writing Vocabularies Acquisition for Deaf Learners," in2016 IEEE 16th International Conference on Advanced Learning Technologies (ICALT), 2016/12/24 2016: IEEE, pp. 441-445, doi: 10.1109/ICALT.2016.127.
[8] M. John *et al.*, "An Automated Technique for Real-Time Production of Lifelike Animations of American Sign Language," Universal Access Inf, vol. 15, no. 4, p. 551 566, 2016, doi: 10.1007/s10209-015-0407-2.
[9] M. Kipp, A. Heloir, and Q. Nguyen, "Sign language avatars: Animation and comprehensibility," in International Worskop on Intelligent Virtual Agents, Reykjavik, Iceland, 2011 2011: Springer, pp. 113-126.
[10] B. Manini *et al.*, "Physiological and behavioral correlates of babies' social engagement with robot and virtual human artificial intelligence agents.," in Society for Research in Child Development, Austin, TX, 2017.
[11] N. Courty and S. Gibet, "Why is the creation of a virtual signer challenging computer animation?," Motion in Games 2010, Nov 2010, Netherlands. pp.1-11.
[12] M. Agarwal, "Learn American Sign Language using Mixed Reality (Hololens)? Yes, we can!," in Virtual Reality Pop, 2017, https://virtualrealitypop.com/learn-american-sign-language-using-mixed-reality-hololens-yes-we-can-e6e74a146564?
[13] G. Cadeñanes and A. González, "Augmented reality sign language teaching model for deaf children," In Distributed Computing and Artificial Intelligence, 11th International Conference (pp. 351-358). Springer, Cham. doi: 10.1007/978-3-319-07593-8_41.
[14] Q. Shao *et al.*, "Teaching American Sign Language in mixed reality," in revision.
[15] C. Kontra, D. Lyons, S. Fischer, and S. Beilock, "Physical experience enhances science learning," Psychologial Science, vol. 26, no. 6, 2015, pp. 737-749, doi: 10.1177/0956797615569355.
[16] L. C. Quandt and P. Marshall, "The effect of action experience on sensorimotor EEG rhythms during action observation," Neuropsychologia, vol. 56, pp. 401-408, 2014, doi: 10.1016/j.neuropsychologia.2014.02.015.
[17] M. Kiefer and N. M. Trumpp, "Embodiment theory and education: The foundations of cognition in perception and action," Trends in Neuroscience and Education, vol. 1, no. 1, 2012, pp. 15-20.
[18] C. Kontra, S. Goldin-Meadow, and S. Beilock, "embodied learning across the life span," Topics is Cognitive Science., vol. 4, no. 4, pp. 731-739, 2012, doi: 10.1111/j.1756-8765.2012.01221.x.
[19] S. M. Weisberg and N. S. Newcombe, "Embodied cognition and STEM learning: overview of a topical collection in CR:PI," Cognitive Research: Principles and Implications, vol. 2, 2017, pp. 1-6, doi: 10.1186/s41235-017-0071-6.
[20] M. C. Johnson-Glenberg, C. Megowan-Romanowicz, D. A. Birchfield, and C. Savio-Ramos, "Effects of embodied learning and digital platform on the retention of physics content: centripetal force," Frontiers in Psychology, vol. 7, 2016, p. 1819.
[21] K. Emmorey, E. Klima, and G. Hickok, "Mental rotation within linguistic and non-linguistic domains in users of American sign language," Cognition, vol. 68, no. 3, pp. 221-246, 1998, doi: 10.1016/S0010-0277(98)00054-7.
[22] J. Pyers, J. E. Perniss, and K. Emmorey (2015). "Viewpoint in the visual-spatial modality: The coordination of spatial perspective." Spatial Cognition & Computation, vol. 15 no. 3, 2015, pp. 143-169.
[23] J. Kätsyri, K. Förger, M. Mäkäräinen, and T. Takala, "A review of empirical evidence on different uncanny valley hypotheses: Support for perceptual mismatch as one road to the valley of eeriness," Frontiers in Psychology, vol. 6, 2015, doi: 10.3389/fpsyg.2015.00390.
[24] A. P. Saygin, T. Chaminade, and H. Ishiguro, "The perception of humans and robots: uncanny hills in parietal cortex," Proceedings of the Annual Meeting of the Cognitive Science Society, vol. 32, 2010, pp. 2716-2720.
[25] S. Schindler, E. Zell, M. Botsch, and J. Kissler, "Differential effects of face-realism and emotion on event-related brain potentials and their implications for the uncanny valley theory," Scientific Reports,vol. 7, doi: 10.1038/srep45003.
[26] T. Ono, A. Kimura, and J. Ushiba. "Daily training with realistic visual feedback improves reproducibility of event-related desynchronisation following hand motor imagery," Clinical Neurophysiology, vol. 124, no. 9, 2013, pp. 1779-86.