# Evaluation of HaptiComm-S for Replicating Tactile ASL Numbers: A Comparative Analysis of Direct and Mediated Modalities

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**Abstract.** This research investigates the efficacy of HaptiComm-S, a haptic communication device designed to facilitate tactile communication for Deafblind individuals. The primary focus is on evaluating the device's capability to replicate the tactile American Sign Language (ASL) numbers 0 to 10. Participants performed under two distinct conditions: direct ASL signing and mediated ASL signing through two modalities (Tap and Tap-and-Hold). Our findings demonstrate significant differences in performance between the Direct and Mediated ASL modes. Direct ASL consistently exhibited higher accuracy compared to mediated conditions. Mediated ASL conditions were prone to perceptual errors in number identification. Notably, specific numbers, such as 4, 7, 8, and 9, posed challenges in the mediated conditions, often resulting in confusion among participants. These findings contribute valuable insights for the ongoing refinement in the design of haptic communication devices tailored to the needs of the Deafblind community.

**Keywords:** Tactile ASL · Haptic Communication · Deafblindness.

## 1 Introduction

In the realm of assistive technology, ongoing research is focused on innovating communication methods for individuals with disabilities. Developing effective communication tools for deafblind individuals is particularly challenging, given the complex interplay of combined hearing and vision impairments. HaptiComm-S, an innovative haptic communication device, introduces a distinctive approach to tactile communication. Developed with the aim of exploring and broadening the capabilities of haptic technology, HaptiComm-S focuses on simulating Tactile Fingerspelling (TFS) and Tactile American Sign Language (TASL). These modes of communication are essential for Deafblind individuals, involving specific hand-touch movements to convey letters and numbers. Our objective was to evaluate the efficacy of HaptiComm-S in conveying numbers from 0 to 10 to users' hands. To achieve this, an experiment was designed involving individuals without sensory impairments as test participants. The use of non-expert users in this initial phase served a dual purpose: firstly, to refine the technology functionally before introduction to the target audience, and secondly, to obtain a baseline performance of the device in a controlled setting.

## 2 Related Work

The development and refinement of assistive communication technologies for Deafblind individuals spanning three decades (refer to [11] for a comprehensive review), underscores a continual effort to improve autonomy and social inclusion. The focus on developing tactile communication devices aligns with the broader goal of enhancing interaction. Wearable Human-Machine Interfaces (HMIs) are gaining prominence, transitioning from traditional touch sensors to more sophisticated e-skin technologies [8].

Earlier studies extensively explored assistive devices for Deafblind individuals. Notable examples of device development include Dexter, a mechanical fingerspelling hand aiding communication and DB-HAND, a hardware/software system facilitating autonomous interaction [1, 6]. Building upon these foundations, the Finger Braille Teaching System [5] demonstrated non-disabled individuals' ability to communicate with Deafblind individuals using Braille code. Similarly, Reed et al. [12] explored a tactile speech device translating phonemic codes through tactile stimulation, and Ozioko [10] presented a wearable tactile communication interface employing finger Braille, integrating actuation and sensing in the same location.

In recent years, there has been a substantial focus on developing wearable and glove-like technologies based on existing tactile communication languages and methods. The Mobile Lorm Glove, which translates the Lorm hand-touch alphabet into text messages [3], exemplifies this trend. Other wearable devices facilitating communication using tactile methods have explored the use of the British Deafblind manual alphabet and Braille [9], as well as the Malossi alphabet [1]. Additionally, Hirose and Amemiya [4] introduced Finger-Braille interfaces integrated with wearable computers, and Nicolau et al. [7] presented UbiBraille, a device leveraging Braille knowledge for reading electronic texts.

## 3 Experiment

### 3.1 Participants

Twenty participants (8 F, 12 M, mean age = 29.85, SD = 6.02) were recruited from Bentley University and duly compensated for their involvement. None reported hearing or visual deficits, hand injury, or nerve damage. The experimental procedure adhered to the Declaration of Helsinki guidelines, and the study protocol received approval from the Institutional Review Board of Bentley University.

### 3.2 Apparatus

Building upon the HaptiComm device [2], the HaptiComm-S was tailored for users with smaller hand sizes. The original design was scaled down by a factor of 0.85 and an increased height of 20 mm to reduce magnetic interference. It incorporates an array of twenty-four custom-made electrodynamic actuators, each meticulously positioned to deliver distinct tactile sensations. Users place their left hand on the device, enabling them to perceive tactile stimuli (Fig. 1).

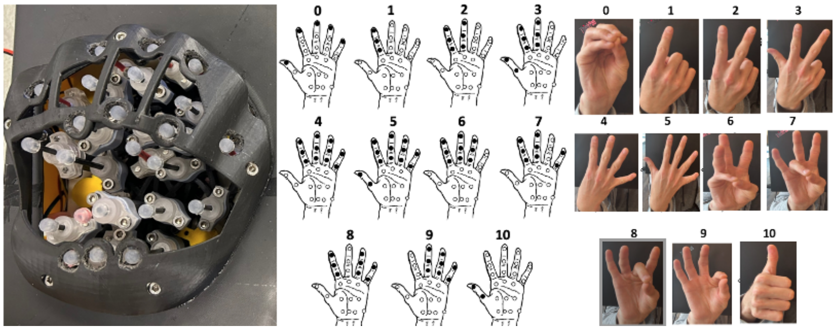

Fig. 1: Left) HaptiComm-S, Center) Mediated TASL as provided by the HaptiComm-S, and Right) ASL numbers.

### 3.3 Stimuli

We focused on TASL, a specific method of tactile communication where a deaf-blind individual discerns signs by placing a hand over that of the signer. This study evaluated the HaptiComm-S device's ability to transmit TASL numbers 0 to 10 under two conditions: Tap and Tap-and-Hold. In the Tap condition, participants experienced brief 40 ms taps, whereas in the Tap-and-Hold condition, the contacts lasted 200 ms. The control condition utilized direct TASL, where participants identified numbers by physically grasping the experimenter's hand to feel each fingering position. In the mediated conditions, the HaptiComm-S system replicated these positions by activating the corresponding actuators to simulate the sensation of the specific fingers used in direct TASL, delivering either short or long taps to mimic the actual finger positions. Figure 1 visually depicts the mediated TASL numbers as interpreted by the HaptiComm-S, in comparison to traditional TASL.

### 3.4 Procedure

Following informed consent, participants watched a video tutorial demonstrating ASL numbers 0 to 10, which was shared with them a day before the experiment.

Upon arrival at the experimental site, we verified their comprehension by requesting that they manually sign the numbers as a prerequisite for commencing the experimental tasks.

The experiment consisted of three randomized blocks, each comprising 33 trials (3 x 11 numbers): 1) Direct ASL Signing, 2) Mediated ASL Signing with the Tap condition, and 3) Mediated ASL Signing with the Tap-and-Hold condition. In the Direct ASL block, participants identified numbers by holding the experimenter's hand with their left hand and releasing it immediately after providing their answer. In the Mediated ASL Signing blocks, participants initially familiarized themselves with numbers activated by the HaptiComm-S device, receiving feedback on their responses, and subsequently identified the numbers delivered on their left hand.

Numbers were presented in a randomized order within each block. To minimize visual and auditory distractions, participants wore blindfolds and noise-canceling headphones. A 5-minute break occurred following each block before proceeding to the next. For each trial, participants verbally reported the perceived number before advancing to the next trial. Upon completing all blocks, participants assessed the difficulty level of the tasks and provided feedback on their overall experience.

## 4 Results

A two-way repeated measures ANOVA examined the impact of the ASL condition and Number on correct responses. Results revealed a significant main effect of Condition, $F(2, 38) = 98.38$, $p < .001$, $\eta_p^2 = .84$, indicating a substantial effect size. Similarly, a significant main effect of Numbers was observed, $F(10, 190) = 18.30$, $p < .001$, $\eta_p^2 = .49$, with a large effect size. Moreover, the interaction effect between Condition and Number was significant, $F(20, 380) = 9.61$, $p < .001$, $\eta_p^2 = .34$, suggesting that the effect of Condition on the dependent variable varied depending on the number presented.

Post hoc comparisons, with multiple comparisons, revealed significant performance differences across the three TASL conditions. In the Direct ASL condition, Participants consistently showed better performance with numbers 0 through 10 compared to the same numbers in both ASL Mediated conditions. Specifically, numbers 0, 4, 6, 7, 8, and 9 exhibited systematically higher performance in the Direct condition. Within the Mediated conditions, numbers 1, 2, 3, and 5 demonstrated higher performance relative to 7, 8, and 9 (Fig. 2).

### 4.1 Discussion and Conclusion

Our findings consistently highlight an advantage for Direct TASL across all numbers, underscoring the significant impact of the modality on performance. Within the Mediated conditions, performance was generally strong for numbers 0, 1, 2, 3, 6, and 10. However, accuracy declined in perceiving numbers 4, 7, 8, and 9, which were frequently misidentified. The confusion matrix for the direct ASL

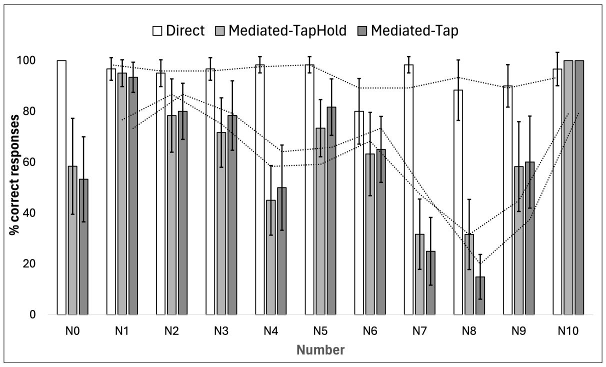

Fig. 2: Barplots for the three ASL conditions. Error bars represent 95% confidence intervals. The moving average is displayed for each condition.

condition reveals high accuracy in participant responses, with correct identification rates predominantly ranging from 92% to 100%. This indicates effective communication of tactile ASL numbers by the human signer.

Contrastingly, the mediated ASL conditions face challenges with specific numbers. Notably, the number 4 in the Tap condition was often confused with 9 (22%), while in the Tap-and-Hold condition, it was frequently mistaken for 6 (13%), 7 (10%), 8 (10%), and 9 (12%). This pattern arises from the similarities in the mediated TASL for these numbers, where three fingers represent 6, 7, 8, and 9, and four fingers denote 4. Additionally, number 7 was consistently confused with 4 in both mediated conditions (42% and 35%), and the number 8 was frequently misidentified as 4, particularly in the Tap condition (55%) and to a lesser extent in the Tap-and-Hold condition (35%). The decision to maintain the natural hand configurations used in ASL for coding numbers on the HaptiComm-S device was intentional, aimed at minimizing the learning curve by leveraging pre-existing knowledge of ASL and to avoid introducing an entirely new signing method. Overall, the confusion matrices reveal perceptual errors, highlighting specific numbers more susceptible to misinterpretation in mediated conditions compared to direct human ASL (Fig. 3). This observation is corroborated by participants' evaluations of task difficulty on a 7-point scale (1–very easy, 7–very difficult). In the direct ASL condition, the average task difficulty was 1.65 (SD=0.89), whereas for the mediated conditions, task difficulty had an average score of 4.85 (SD=1.51). Most participants indicated the task with a human signer as easier than with the HaptiComm-S, reporting challenges in distinguishing between 7, 8, and 9 on the Hapticomm-S.

Unlike letters, which can be contextually corrected within words, numbers demand precise delivery as they lack contextual cues for correction. Subsequent studies should explore alternative aspects of stimuli, such as the time interval between actuators or the spatial pattern of stimuli. Tactile ASL, encompassing both letters and numbers, necessitates incremental learning, practice, repetition,