Feeling Speech on the Arm

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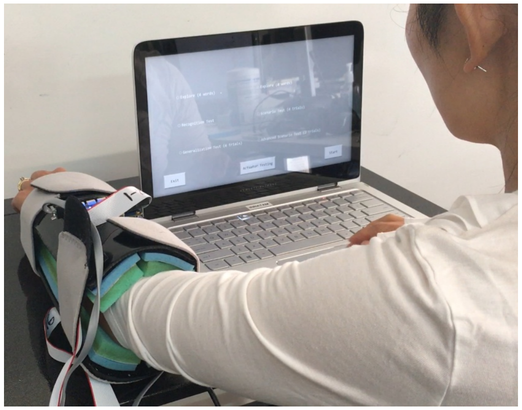

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Abstract

In this paper, we introduce a transcutaneous language communication (TLC) system that transmits a tactile representation of spoken or written language to the arm. Users receive messages without looking at their smart devices, and feel them through their skin. We will demonstrate an application that helps users get acquainted with our TLC system, learn building blocks for a small vocabulary and generalize them to new words – all within 3-5 minutes on the demo. Finally, the applications of the TLC system for normal and impaired individuals are discussed.

Author Keywords

Vibrotactile; touch; haptic language; transcutaneous language communication; learning.

ACM Classification Keywords

H.5.2. User Interfaces: Haptic I/O

Introduction

Touch and vibration have been shown to be feasible methods of communication. As early as 1800s, braille was invented to enable visually impaired to read by touching raised dots with their fingers [3]. In 1932, deaf-blind people could receive spoken language by feeling the vibration and movement of speaker's lips, face and throat with their hand, termed Tadoma method [1]. While vibrotactile communication has largely been adopted by people with impaired vision or hearing, its application for sighted and hearing people

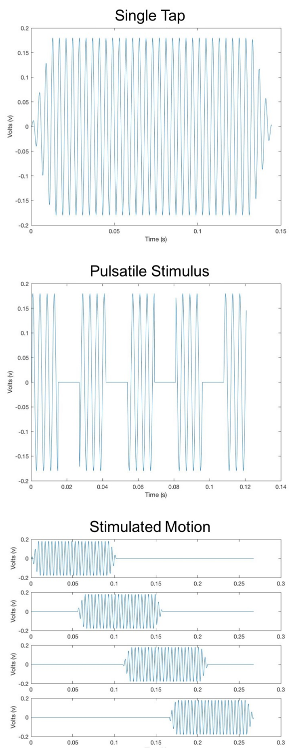

Figure 1: Haptic stimuli used for delivering stationary and motion percepts.

has not been well considered yet. Thanks to the invention of smartphones and wearable devices, on average, smartphone users check their devices 47 times per day [5]. New rules of smartphone etiquette thus start to emerge. It is not socially acceptable to check the devices during a meeting, a movie, or at other places where others are quiet like at church or a worship service [9], but it can be devastating to miss important call, text, or notification from a loved one or a caregiver while following etiquette.

Clearly, there is a need to build a system that can transmit messages to the receiver without disturbing people around the receiver, especially if the message requires immediate attention. We introduce a transcutaneous language communication (TLC) system, designed to serve such needs by coding the spoken or written language into phonemes and transmitting the phonemes to the arm in a vibrotactile format. The phonemic approach is used because a phoneme is the unit of spoken language and is applicable to all languages. In addition, a word on average contains less phonemes than letters [2,6], making phonemic information transfer faster and less taxing of cognitive resources for the user. We use the forearm as the medium because it has a better tactile sensitivity than most body parts [7], less likely to disrupt daily activity compared to the hand, and more socially acceptable than the forehead or feet. In this paper, we will detail: our haptic devices, the design rules underlying the haptic stimuli, how we pair and verify the phonemes to the haptic stimuli, and demonstrate our learning application, in which a person can learn 4 phonemes in 3 minutes and generalize the learning to words and phrases in different real-world scenarios.

Apparatus

The haptic stimuli will be presented on our vibrotactile device, which consists of two 8-tactor displays. The tactors are voice coils surrounded by a 3-D printed case, embedded in a foam sheet, and arranged in a 4 x 2 grid with 1.5” lateral and 2” longitudinal spacing in between the tactors. The tactors and foam are attached to a rigid thermoformed arced surface to make a wearable display. The displays are placed on the dorsal and volar sides of the forearm (Figure 1).

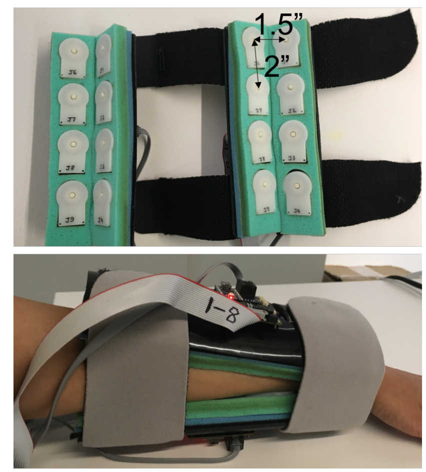

Figure 1: Haptic displays used in TLC system.

Haptic Stimuli

The haptic stimuli will be delivered as either a 250 Hz sinusoidal wave or 15 ms bursts of a 250 Hz sinusoidal wave every 27 ms (Figure 2) via Max/MSP software using a MOTU 24Ao audio interface and a stereo amplifier. The duration for a single tap is 144 ms. Motion cues last 267 ms, with four 102-ms-long tactors

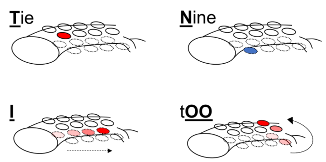

Figure 3: Haptic-phonemic pairs used in the demo.

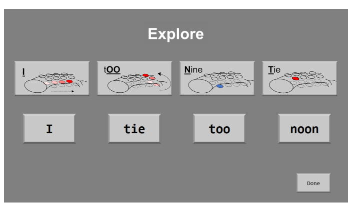

Figure 5: User interface during Explore.

firing at 55 ms stimulus-onset asynchrony (SOA). These all include a 10% ramp time.

Location and Motion Cues
Past studies have shown that tactors closer to body landmarks, such as the wrist and elbow, are localized more accurately [4], so the single tap stimuli are designed close to the wrist and elbow. Linear and circular motion cues used 4 tactors, which were identified as sufficient to elicit reliable linear and circular motion using a vibrotactile device [8].

Haptic-Phonemic Pairing
Our TLC system is coded by a phonemic approach, meaning that each haptic stimulus is paired with a phoneme based on the place, manner, and voice of articulation [10]. For example, /ba/, /da/, and /ga/ are articulated at the lips, gum, and roof of the mouth, respectively, so they will be paired to a haptic stimulus at the wrist, elbow, and upper arm in accordance to the place of articulation. Since voiced consonants have more energy and voiceless consonants are only made with air, voiced consonants (e.g., /ba/ and /da/) are paired with bursts of a sinusoidal wave while voiceless consonants (e.g., /pa/ and /ta/) are paired with an original sinusoidal wave. Moreover, consonants are produced with more airflow constriction compared to vowels, so vowels are designed as motion gestures while consonants are single taps. See Figure 3 for examples of haptic-phonemic pairing.

Demonstration

Our demonstration shows that naïve users can quickly learn the tactile coding, generalize it to new words, and use them in structured sentences for everyday discreet communication, all within 3 minutes.

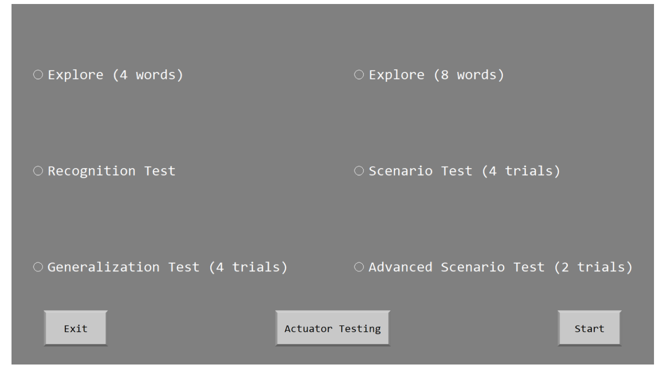

Figure 4: User interface of the main menu in the demo.

Explore
The learning starts with Explore, where users can click any phoneme or word (Figure 5) in any order and as many times as they want to feel and learn the corresponding haptic stimuli. Users can learn at their own pace and move on to the test once they are ready.

Recognition Test
Each trial starts with a 600 ms fixation point, followed by a haptic stimulus from the list of words in Explore (Figure 6). Users can click the “Replay” button, if needed, to replay the haptic stimulus before choosing the answer. Feedback is provided and the user can replay the haptic stimulus. The inter-trial-interval (ITI) is 400 ms.

Generalization Test
The Generalization Test is similar to the Recognition Test, except that the words tested are new; they haven’t been presented to the user before.

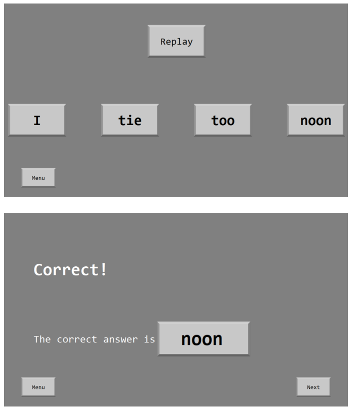

Figure 6: User interface during response (top) and feedback (bottom) in Recognition Test.

Figure 7: User interface during Scenario Test.

Scenario Test

A scenario question will be displayed on the screen (e.g., What time is the meeting? How does the dress fit?) The answer to the question will be presented on the haptic displays (Figure 7). To receive the answer, the user clicks the "Answer" button. The answer is one or two words that the user has seen in Explore, Recognition Test, and Generalization Test. Feedback will be provided, and the users have the choice to replay the answer again.

Application

The scenario test gives some examples of the application of our TLC system, like the meeting time. In short, the users can receive meaningful messages on their arms by feeling the vibrotactile stimuli, instead of inconveniently taking out and looking at their smart devices. In addition, this TLC system can also be adopted by people with or without visual or auditory impairment. For the blind, fingers can be freed to type while receiving the messages through the arm. For people with impaired hearing, their visual sense will no longer be overwhelmed by sign language and other visual information; they can divert the sensory inputs to more than one modality. Blind-deaf people can do speechreading independently and easily without the presence of a speaker and placing their hand on the speaker's face.

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