Tactile Communication of Speech

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Goals and Significance

The long-term goal of this research is to develop tactual aids for persons who are profoundly deaf or deaf-blind to serve as a substitute for hearing in the reception of speech and environmental sounds. This research can contribute to improved speech reception and production, language competence, and environmental-sound recognition in such individuals. This research is also relevant to the development of improved tactual and haptic displays for a broad class of applications (including virtual-environment and teleoperator systems in addition to sensory aids).

Research is being conducted in two major areas. Work in *Area 1* (Basic Studies of Human Touch) is designed to increase our knowledge concerning the transmission of information through the sense of touch. This research includes theoretical and experimental studies concerned with dynamic information transfer as well as experimental work designed to increase our understanding of the psychophysical properties of the sense of touch. Work in *Area 2* (Tactual Displays of Speech and Environmental Sounds) is concerned with the application of tactual displays to sensory aids for persons who are profoundly deaf or deaf-blind. This research includes studies related to the processing and display of speech and environmental sounds through the tactual sense as well as studies concerned with evaluations of performance achieved through these displays.

Current Studies

Basic Studies of Human Touch.

Measurement of Information-Transfer Rates for Multidimensional Tactual Signals.

Research in this area is directed towards an improved understanding of the properties that contribute to optimizing information-transfer (IT) rate. Such knowledge is important not only in connection with the design of improved aids for persons with sensory impairments, but also in connection with the design of improved displays for normally-sensed users of data visualization systems and synthetic environments. In previous research (Tan et al., 1999; Tan et al., 2003), we relied on a set of hypotheses to estimate tactual information-transfer (IT) rates from experiments where the subject's task was to identify one signal in a specified location within a sequence of two or three consecutive stimuli (using backward, forward, and sandwiched masking paradigms). Experimental studies are currently being conducted to determine the extent to which the estimations of IT rate derived from these previous studies can be generalized to situations in which the subject is required to identify each signal in a series of consecutively presented stimuli. Estimates of IT rate obtained in tasks requiring the identification of two or three stimuli presented sequentially are somewhat lower than those obtained in an AXB procedure (where the subject identifies only the middle stimulus in a sequence of three stimuli). The rates achieved in these sequential identification tasks (4 to 12 bits/sec) are nonetheless sufficiently high to provide support for communication of speech (e.g., as a means of presenting cues to supplement the information available through speechreading).

Development of Tactual Stimulator Device.

A new version of our multi-finger tactual stimulating device has been developed for use in experimental studies to be carried out at our sub-contractual site at Purdue University. The controller system employed in the new design produces a closed-loop transfer function that follows the human detection-threshold curve. This new design will permit the device to be driven with a broadband signal (up to 300 Hz) while preserving the relative intensity of different spectral components in terms of the relative sensation levels delivered by the device.

Tactual Displays of Speech and Environmental Sounds

Improved Tactual Displays of Consonant Voicing.

Research in this area includes exploration of signal-processing schemes to extract voicing information from the acoustic speech signal, methods of displaying this information through a multi-finger tactual stimulating device, and perceptual evaluations of voicing reception through the tactual display alone (T), lipreading alone (L), and the combined condition (L+T). The signal-processing scheme for extraction of voicing information employs amplitude-envelope signals derived from two filtered bands of speech: a lowpass-filtered band at 350 Hz and a highpass-filtered band at 3000 Hz). Acoustic measurements of the envelope signals derived from a set of 16 initial consonants represented through multiple tokens of CVC syllables indicate that the onset-timing difference between the low- and high-frequency envelopes (EOA: envelope-onset asynchrony) provides a reliable and robust acoustic cue for distinguishing voiced from voiceless consonants. This acoustic cue was presented through a two-finger tactual display such that the envelope of the high-frequency band was used to modulate a 250-Hz signal delivered to the index finger and the envelope of the low-frequency band was used to modulate a 50-Hz signal delivered to the thumb. The temporal-onset order threshold for these two signals, measured with roving signal amplitude and duration, averaged 34 msec, sufficiently small relative to the magnitude of EOA. Studies of pair-wise discrimination in eight pairs of initial-consonant voicing contrasts in CVC syllables indicated that use of the cue led to high levels of performance under the T and L+T conditions (roughly 90% correct) compared to L (roughly 50%, i.e., chance). The identification of 16 consonants was improved by roughly 15 percentage points with the addition of the tactual cue over L alone, due in large part to improved performance on the feature of voicing. No improvements were noted, however, in L+T over L alone for reception of words in sentences, indicating the need for further training with connected speech.

Survey on Reception of Environmental Sounds: Opinions of Deaf and Hard-of-Hearing Persons.

Results have been summarized for a pilot survey concerned with determining the interest of deaf and hearing-impaired persons in the reception of various types of environmental sounds. The survey consisted of 65 multiple-choice questions in four different areas: communication preferences, history of assistive-device use, interest in various types of environmental stimuli, and preferences regarding the design of devices for displaying acoustic environmental stimuli. The respondents were 20 deaf adults who ranged in age from 20 to 52 years, described themselves as either deaf or hard-of-hearing, and were either born deaf or had acquired hearing loss before the age of 2 years. Subjects were divided into two groups based on their linguistic preference: a group who had early exposure to and preferred manual communication and a group who preferred oral communication. The responses of the two groups indicated similar degrees of interest in the reception of various types of environmental sounds and in characteristics related to the design of communication devices. A summary of the major results of the survey indicates that the subjects were most interested in receiving information about sounds associated with warning signals and operation of machinery (such as cars) and prefer a multi-purpose, portable alerting system that can used with minimal training.

Publications

Reed, C.M., and Delhorne, L.A. (2003). "Tactual Aids and Environmental Sounds," Ear and Hearing, 24, 528-538.

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