signal for the control of phonation than the airborne sound. Phonatory vibrations have been examined in previous research. The results suggest that in singing at fundamental frequencies lower than about 350 Hz (pitch F4) chest wall vibrations can be used as a feedback signal, as they seem to reflect glottal adduction, an aspect of great relevance to singers. Vibrations in the face and skull, on the other hand, seem to vary considerably between different vowels and thus seem to depend on formant frequencies rather than on voice source characteristics. Therefore such vibrations can be assumed to be more difficult to use as a feedback for controlling phonation.

9:35

5aBV4. The role of tactile and kinesthetic feedback in speech production. Katherine S. Harris (Dept. of Speech and Hear. Sci., Graduate School, City Univ. of New York, 33 W. 42nd St., New York, NY 10036 and Haskins Labs., New Haven, CT 06511)

Since sensory-motor integration is a central topic in studies of limb movement, one might expect studies of the role of kinesthesis and taction to have a central role in one's understanding of the motor organization of speech production. However, perhaps because of the lack of a fully adequate animal model for speech, or because of the inacessibility of the articulators to experimental manipulation, the literature is quite limited. This paper will review existing experimental studies, as they fall under four headings: (1) the effect of reduction of tactile and kinesthethetic feedback from the articulators; (2) the effect of experimental static alteration of the relationship among the articulators, such that feedback from them is altered during articulation; (3) the effect of transient mechanical perturbation of articulation; (4) comparison of the role of taction and kinesthesis in the speech of normals and individuals with severe and profound hearing impairment, for whom auditory feedback cannot have its normal role in speech acquisition. [Work supported by NIDCD.]

10:05–10:15 Break

Contributed Papers

10:15

5aBV5. Tactile feedback from brass instrument shell and air column vibrations. Peter L. Hoekje and David Kjar (Dept. of Phys., Univ. of Northern Iowa, Cedar Falls, IA 50614-0150)

The vibrations of the metal shell of a brass instrument can be discerned by the player through the player's lips and hands. This is in addition to the vibrotactile feedback to the player's lips from the acoustic vibrations in the air column of the instrument. Many players claim an improvement in playability when the mass of the mouthpiece is increased. Measurements of the body vibrations of a trumpet under playing conditions were obtained with an accelerometer at six locations: at three points on the mouthpiece, and also on the receiver, valve casing, and bell. The greatest amplitudes were observed at the bell. When mass was added to the mouthpiece, while keeping the sound level output of the instrument constant, the vibration amplitudes at the mouthpiece decreased as expected. However, the same degree of decrease was not observed at the other locations. This and other evidence suggests that increasing the mouthpiece mass does not significantly alter the coupling between the air vibrations and the shell vibrations. Thus, it is postulated that the playability benefits derive from a reduction in the conflict between the two channels of feedback to the lips.

10:30

5aBV6. Vibrations in violins with tuned fingerboards: A case study of instrument feedback. Erik V. Jansson and Anders Askenfelt (Dept. of Speech Commun. and Music Acoust., Royal Inst. of Technol., P.O. Box 700 14, S-100 44 Stockholm, Sweden)

All traditional musical instruments vibrate more or less during playing. These vibrations serve as a silent feedback from the instrument to the musician, and the feedback is likely to be an important component of the instrument response. Work has been done to study if an enhanced vibration level in the violin is perceived as favorable by the musician, and if such a change results in a change in playing. The vibration level in the instrument was varied by tuning a fingerboard resonance in relation to the Helmholtz's resonance (A0). The level was measured prior to and after the tuning of the fingerboard, using two "types" of violinists; a PC-controlled bowing machine and professional violin players, respectively. The quality of the instrument as judged by the musicians with and without tuned fingerboard, respectively, gives an estimation of the degree of feedback from instrument to player. [Work supported by the Swedish Council for Research in the Humanities and Social Sciences.]

10:45

5aBV7. The effects of hyperbaric conditions on vibrotactile thresholds. Stanley J. Bolanowski, Ronald T. Verrillo (Inst. for Sensory Res., Syracuse Univ., Syracuse, NY 13244-5290), Frances Baran, and Paul F. Smith (Naval Submarine Base, New London, Groton, CT 06349-5900)

The effects of low-frequency, water-borne vibration upon swimmers and divers are virtually unknown. It has been reported that divers can "feel" underwater sounds on various parts of their bodies. The current experiments were conducted as an initial investigation of these reports to determine if barometric pressure and breathing mixture has an effect on vibrotactile thresholds measured in air. Vibrotactile thresholds at the thenar eminence were determined on four divers during a "saturation dive" (8 days) in a dry hyperbaric chamber. Measurements were made prior to the dive (pre-test) in a normobaric environment (sea level) at 132 ft of seawater (fsw), at 198 fsw, at 300 fsw, and following the dive at sea level (post-test). The gas mixture in which the divers lived was varied according to standard procedures to prevent adverse body reactions during compression and decompression. Vibrotactile thresholds were measured by standard procedures at 1, 10, 100, and 250 Hz. Results indicate that neither air pressure nor breathing mixture had any effect on vibrotactile thresholds within any of the four mechanoreceptor channels that innervate normal skin. The results are internally consistent within this experiment and also when compared to threshold standards accumulated over thirty years. [Work supported by Geo-Centers, Inc. under Navy Contract.]

11:00

5aBV8. Tactual performance with motional stimulation of the index finger. Hong Z. Tan, Nathaniel I. Durlach, William M. Rabinowitz, and Charlotte M. Reed (Res. Lab. of Electron., MIT, Cambridge, MA 02139)

The results of two studies investigating performance with motional stimulation applied to the finer will be reported. Experiments were conducted using a position-controlled servomotor that delivers large-amplitude displacements in the frequency range of 1–32 Hz to the fingerpad of the index finger. In one study, measurements of amplitude

and frequency discrimination were obtained as a function of reference frequency, reference displacement, and duration. Results obtained for low-frequency motional stimulation will be discussed and related to results reported in the literature for vibrational frequencies. In a second study, computer-generated sequences of International Morse code were delivered to the fingertip using high-amplitude square-wave stimulation. The ability to identify Morse code sequences was studied as a function of rate of presentation and length of the stimulus stream for subjects who were either naive or highly experienced in the traditional sending and receiving of Morse code. Results will be discussed in terms of the differences in learning and information transmission rates between naive and experienced subjects. [Work supported by NIDCD.]

11:15

5aBV9. Tactile and auditory measures of modulation resolution. W. M. Rabinowitz, C. M. Reed, L. A. Delhorne (Res. Lab. of Electron., MIT, Rm. 36-789, Cambridge, MA 02139), and J. M. Besing (Louisiana State Univ., Baton Rouge, LA 70803)

Limited signals derived from speech can provide effective supplements to speechreading. For a single-band speech envelope that is used to modulate a 200-Hz tone, the benefit to speechreading is, however, greater with auditory than tactile presentation. Is this due to differences between hearing and touch in the psychophysical ability to perceive amplitude modulation changes? Experiments are being conducted to assess amplitude modulation discrimination as a function of reference modulation depth ($m=0$ to 1) and modulation frequency ($f_m=5$ or 50 Hz). Carrier frequency is fixed at 200 Hz and stimulus presentation is via headphone for audition and a minishaker for taction. Preliminary results indicate that, on average, auditory thresholds for Δm are roughly 6 dB more sensitive than tactile thresholds. These results extend those previously available in the literature by considering cases of nonzero reference values for m, which may be particularly relevant to the information that is conveyed in the single-band speech envelope. [Work supported by NIDCD.]

11:30

5aBV10. Examining the effects of long-term experience using tactile supplements to speechreading. Edward T. Auer, Lynne E. Bernstein (Ctr. for Auditory and Speech Sci., Gallaudet Univ., 800 Florida Ave., N.E., Washington, DC 20002), and David C. Coulter (Coulter Assoc., Fairfax, VA 22031)

Typically, studies evaluating tactile supplements to speechreading are relatively short in duration and limited to the laboratory. Results from an ongoing 10-month study of the effectiveness of four tactile devices will be presented. Two devices encode voice fundamental frequency ($F0$): One encodes $F0$ as rate of vibration of a single solenoid, and the other as both rate and location of vibration on a linear array of eight solenoids. Two devices are 16-channel vibrotactile vocoders: One encodes wideband speech spectral information, and the other encodes the $F2$ range of frequencies. Subjects are adults with pre- and post-lingual profound hearing impairments and are each assigned to use a single device for the duration of the study. Some of the subjects assigned to the single channel $F0$ device are also using a wearable version outside the laboratory. Comparisons of the effectiveness of all four devices over long-term exposure are being conducted using both traditional performance measures and novel measures of on-line cognitive processing. To data, 10–20 percentage point improvements in identification of words in sentences have been observed with the single channel device.

11:45

5aBV11. Effects of haptic movement on tactile pattern identification. Janet M. Weisenberger (Speech and Hear. Sci., Ohio State Univ., Columbus, OH 43210) and Christopher J. Hasser (Human Systems Ctr., Air Force Materiel Command, Wright-Patterson AFB, OH 45433)

Craig [Percept. Psychophys. 30, 151–166 (1981)] found that tactile perception of complex vibratory patterns presented to the fingertip was better for "static" patterns that did not move across the display than for "scan" patterns that moved horizontally across the display. It is possible that Craig's finding resulted from the fact that observers did not have active control of the movement of the scan patterns. In the present work, tactile patterns were presented to the fingertip under three modes: a static mode in which stimuli did not move; a passive scan mode in which stimuli moved horizontally across the display under a stationary fingertip; and a haptic scan mode in which observers moved the fingertip and the display across a virtual surface containing the stimulus. Results with a set of simple patterns showed no differences across modes, with all modes yielding performance greater than 90% correct. To eliminate the possibility of ceiling effects, a second experiment was conducted with a more complex stimulus set. Preliminary results showed lower levels of performance for all presentation modes, with the haptic scan mode showing the best performance. Results are discussed in terms of development of tactile displays for sensory communication and telerobotics applications.

FRIDAY MORNING, 10 JUNE 1994 STUDENT CENTER, ROOM 407, 8:00 A.M. TO 12:15 P.M.

Session 5aNS

Noise and Structural Acoustics and Vibration: Active Noise and Vibration Control

Paul J. Remington, Chair

BBN Systems and Technologies Corporation, 10 Moulton Street, Cambridge, Massachusetts 02138

Contributed Papers

8:00

5aNS1. Passive-active isolator control of sound radiation from a raft-cylinder system. C. R. Fuller and E. Toffin (Vibration and Acoust. Labs., Dept. of Mech. Eng., VPI & SU, Blacksburg, VA 24061-0238)

This paper analytically investigates the active-passive control of sound radiation from an elastic finite cylinder containing a rigid raft mounted on active-passive isolators. The disturbance is narrow band and acts at various locations on the internal raft. The control cost function is constructed from radiated far-field pressure or supersonic shell structural wave-number estimates in contrast to the usual practice of minimizing vibration directly under the mount attachment point. A control effort term is included in the cost function to overcome the problem of an undetermined system when many isolators are used. The results demonstrate that, using an acoustic-based cost function in conjunction with a fully coupled control approach of the active-passive isolators leads to significant radiated sound reduction with a very low control effort. The mechanism is similar to "modal restructuring" observed in previous plate studies. The results are contrasted to direct