

usually greatest anteriorly. Significant contributions to the volume-velocity waveform were made by the anterior and middle portions of the vibrating vocal folds, while the posterior glottis had less contribution. Inertial delays and flow reversals were demonstrated during the closed phase of phonation. Understanding the measured volume-velocity waveform provides more insight into the acoustic source spectrum and its role in phonation.

2pSC4. Flow visualization in a model of the glottis with a symmetric and oblique angle. Daoud Shinwari, Ronald C. Scherer (Dept. of Commun. Disord., 200 Health Ctr., Bowling Green State Univ., Bowling Green, OH 43403, ronalds@bgnnet.bgsu.edu), Abdollah A. Afjei, and Kenneth DeWitt (Univ. of Toledo, Toledo, OH 43606-3390)

Modeling the human larynx can provide insights into the nature of flow within the glottis. This study reports intraglottal pressure profiles and flow visualization for a symmetric and an oblique glottis with a glottal angle of 10 deg divergence. For the oblique case, the glottis slanted at an angle of 15 deg. A Plexiglas model of the larynx was used. Each vocal fold had at least 11 pressure taps. The minimal glottal diameter was held constant at 0.04 cm. Each case was subjected to steady airflow corresponding to transglottal pressure drops of 3, 5, 10, and 15 cm H₂O. Pressure profile results showed that pressures were different on the two sides of the glottis; these data were strongly supported by an earlier study using a different model. Flow visualization in all cases showed that flow separated from one side of the glottis and remained attached to the other. For the oblique case, the separation point on the divergent wall moved upstream in the glottis with greater flows. The laminar core of the skewed jets decreased in length with higher flows. The jet caused asymmetric circulating regions downstream of the glottis in the reservoir section. [Work supported by NIH.]

2pSC5. Parameters for a first-order Kelvin model of laryngeal muscles. Eric J. Hunter and Ingo Titze (Dept. of Speech Pathol. and Audiol., Natl. Ctr. for Voice and Speech, The Univ. of Iowa, Iowa City, IA 52240, eric-hunter@uiowa.edu)

Because the intrinsic muscles of the larynx determine vocal fold posturing in phonation, a model of vocal fold posturing requires data from the passive and active viscoelastic properties of these intrinsic muscles. Using reported one-dimensional active (twitch and tetanus) and passive muscle (step elongation and relaxation) measures from fresh excised canine laryngeal muscles, one-dimensional first-order Kelvin model parameters were obtained. Obtaining these parameters was accomplished through optimization, where force-elongation patterns predicted by the model were compared to measured muscular passive cyclic force-elongation patterns. These parameters are reported along with the design for the Kelvin model. The results of this study, which will be integrated into a larger finite-element posturing model, become the first step in predicting the vocal fold configurations needed for phonation.

2pSC6. New methods for objective evaluation of nasality. Masanobu Kumada (Dept. of Speech Physiol., Univ. of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo, 113-0033 Japan), Toshiaki Kaneko (Sci. Univ. of Tokyo, Tokyo, 162-0825 Japan), Takahiko Ono, Masanao Ohashi, Koji Ishida (Ono Sokki, Yokohama, 226-8507 Japan), and Seiji Niimi (Univ. of Tokyo, Tokyo, Japan)

New methods for objective evaluation of nasality were introduced, including laser Doppler vibrometer, contact microphone system, and small microphone system. Subjects were two Japanese healthy males who speak Tokyo dialect. Tasks were sustained phonations of five Japanese vowels and /m/, repetitions of /ai/ and /mami/, and Japanese words of /shinknsen/ and /shinbunshi/. Vibration of nasal skin was detected by laser Doppler vibrometer in terms of velocity (*Nv*), and by contact microphone in terms of deviation (*Nc*). Vibration of neck skin on larynx was detected by

contact microphone (*Lc*). Sound radiating from nares was detected by small microphone (*Nm*). Sound radiating from nares and mouth was detected by standard microphone (*Nom*). The accelerometer system was used as standard, consisting of two pickups, one of which detected vibration of nasal skin (*Na*), and the other, neck skin on larynx (*La*). *Nv/Lc*, *Nv/Nom*, *Nc/Lc*, *Nm/Nom* were compared with *Na/La*. These values were normalized as the value for sustained /m/ as 1.0. Clinical use of these new methods was discussed.

2pSC7. Glottal characteristics of children—acoustic measures and comparison with adults. Helen M. Hanson, Kenneth N. Stevens (Sensimetrics Corp., 48 Grove St., Ste. 305, Somerville, MA 02144-2500, hanson@sens.com), and Ralph N. Ohde (Vanderbilt Univ., Nashville, TN 37212)

Previous studies of vowels produced by adult speakers showed substantial individual and gender differences in acoustic parameters related to glottal characteristics [H. M. Hanson, *J. Acoust. Soc. Am.* **101**, 466–481 (1997); H. M. Hanson and E. S. Chuang, *ibid.* **106**, 1064–1077 (1999)]. The current study extends the earlier work to children. In pilot work, data produced by seven children (five male, two female, ages 5-8) showing no signs of speech or voice disorders were analyzed. Acoustic measures related to first-formant bandwidth, open quotient, and spectral tilt were made on the vowel /e/ extracted from the word “red.” These preliminary data show, for example, that the average measure of spectral tilt (dB difference between amplitudes of first harmonic and third-formant prominence) for the children is about 14 dB greater than for adult females and about 24 dB greater than for adult males. The results suggest that, like adults, children display substantial individual differences in vocal-fold configuration. Data for additional subjects and vowels will be analyzed, and we will make measures related to aspiration noise. Mean data for children and adults will be compared and interpretation in terms of acoustic models will be proposed. [Work supported by NIH Grant DC03744.]

2pSC8. Utterance-final voice quality variations: Their perceptual structure and acoustic correlates. Rebecca Herman (Speech Res. Lab., Indiana Univ., 1101 E. 10th St., Bloomington, IN 47405, rherman@indiana.edu)

Voice quality variations can be used to mark prosodic and discourse boundaries in running speech. In order to quantify acoustic events in the signal during the production of these voice qualities, it is necessary to first discover their perceptual structure. The perceptual structure can then inform the acoustic analysis and help to find perceptually salient acoustic correlates. In this study, a perceptual experiment was run in which the stimuli were single words spoken by multiple talkers, which had all been extracted from the ends of utterances. Pairs of stimuli were given similarity ratings by listeners, and the similarity ratings were used in a multidimensional scaling analysis. The dimensions found in the multidimensional scaling analysis were interpreted using acoustic analysis. The voice qualities of the female voices in this study were found to have a primary perceptual split which was interpretable acoustically as laryngealized versus nonlaryngealized, but the voice qualities found in the male voices did not group into categories, and the perceptual dimensions were not as clearly interpretable in acoustic terms.

2pSC9. Phonetic targets as the link between speech production and speech perception. Yi Xu (Northwestern Univ., 2299 N. Campus Dr., Evanston, IL 60208) and Emily Q. Wang (Rush Univ., Chicago, IL 60612)

We argue in this paper that the coherence between speech perception and production, which the motor theory maintains, lies in the common knowledge about speech production shared by the speaker and the listener. More specifically, we propose that abstract phonemic units are associated with phonetic targets that are articulatorily operable. These targets, how-

ever, are usually not fully achieved in speech production. Rather, they are often only approximated by different degrees under the limitation of various articulatory constraints. The process of speech production, therefore, is one in which various phonetic targets are being continuously approximated. As evidence, we will demonstrate with recent acoustic data how lexical tones in Mandarin are implemented through continuous approximation under specific articulatory constraints, how these constraints bring about extensive variations in the F_0 contours, and how, despite the variations, tonal targets maintain their integrity in connected speech. We will then further argue that listeners, being also speakers themselves, should be able to discover the intended targets by noting the consistency the speaker manages to achieve despite the articulatory constraints. In other words, listeners hear not just what the speakers do, but more importantly, what they intend to do: We listen to hear what is being said.

2pSC10. Acoustic vowel space in 13 large Utah families. Kim Corbin-Lewis (Dept. of Communicative Disord. and Deaf Education, Utah State Univ., 1000 Old Main Hill, Logan, UT 84322-1000, KimC@coe.usu.edu), Julie M. Liss (Arizona State Univ., Tempe, AZ 870102), Hilary Coon (Univ. of Utah, Salt Lake City, UT 84113), and Steven D. Gray (Univ. of Utah Med. School, Salt Lake City, UT 84113)

Acoustic vowel space was examined in 131 speakers from 13 large Utah families ranging in age from 20-85 years with a median of 40 years. This population provides a unique opportunity to evaluate speech production characteristics in families with known genetic pedigrees and similar environmental influences. The purpose of the study was to determine whether acoustic manifestations of vowel production could be traceable to gender, age, or family membership. Results indicate that gender by itself explains 43.5% of the variance (highly significant, $p < 0.0001$). Controlling for this gender effect, age is not a significant predictor of vowel space area ($p = 0.29$). However, being in the same family is a significant predictor of vowel space area ($p = 0.002$), independent of effects of gender and age. Being in the same family explains an additional 13.5% of the variance in area. [Work supported by NIH-NIDCD and the W. M. Keck Foundation.]

2pSC11. Individual differences in speech production: Voice-onset-time. J. Sean Allen and Joanne L. Miller (Dept. of Psych., 125 NI, Northeastern Univ., Boston, MA 02115, jallen@lynx.neu.edu)

As part of an ongoing study of talker-specific speech processing, we sought to document the existence of individual talker differences in voice-onset-time (VOT). Four female and four male talkers, all native speakers of American English, were asked to produce 30 repetitions each of 18 different words beginning with /p/, /t/, or /k/. Words were displayed visually on a computer monitor one at a time in a randomized order at a constant presentation rate, and talkers were asked to produce the words at a comfortable speaking rate. The VOT and duration of each spoken word were measured. The eight talkers showed substantial individual variation in speaking rate (as measured by word duration) and, as would be expected, slower speaking rates were associated with longer VOT values. In order to determine whether there were individual differences in VOT beyond those associated with speaking rate, we conducted analyses that controlled for speaking rate on a word-by-word basis. These analyses revealed cases of consistent individual differences in VOT. We are currently examining whether the structure of listeners' perceptual voicing categories reflects such individual talker differences. [Work supported by NIH/NIDCD.]

2pSC12. Perception of speaker characteristics with long and short samples. Blas G. Payri (LIMSI-CNRS, 91403 Orsay Cedex, France)

In this article, the perception of speaker's characteristics is compared using long and short samples. The sound material was an Italian read sentence (seicento-cinquantotto) and the last two syllables "to" from this

sentence. Twenty healthy Italian native speakers (10 females, 10 males) read the sentence, with the same recording conditions. In the first experiment, the listeners performed a free categorization of the syllables and then of the sentences. Then, the listeners were asked to give qualifiers to describe the classes they had made. The aim was to obtain the main criteria for the description of long samples (sentences) and short samples (isolated syllables). For the sentences, the gender and prosody criteria were more frequently used by listeners, whereas the pitch and voice quality were preferred to classify the syllables. In the second experiment, listeners rated the same samples as previously, along predefined axes (age, gender, breath, liveliness, etc.). The ratings were compared with acoustic measures. The results show that the ratings for the whole sentence, and for the extracted syllables, can be significantly different, leading to the conclusion that, within a sentence, there are significant local variations of the perceived voice quality and speaker characteristics as gender and age.

2pSC13. Effects of listener experience on measures of voice quality. Jody Kreiman, Bruce R. Gerratt (Div. of Head and Neck Surgery, UCLA School of Medicine, 31-24 Rehab. Ctr., Los Angeles, CA 90095-1794, jkreiman@ucla.edu), and Melissa Epstein (UCLA, Los Angeles, CA 90095)

Previous studies have shown that clinicians and naive listeners use different perceptual strategies when judging the quality of pathological voices. Naive listeners uniformly rely almost exclusively on F_0 , while clinicians differ substantially from each other in the features they attend to. Consistent differences between groups in the overall level of rating have also emerged in paired comparison tasks, with naive listeners hearing greater differences between stimuli than clinicians do. We hypothesized that these differences in voice ratings are due to task-related factors, rather than to true differences in the ability of the two listener groups to hear differences in voice quality. Analysis-resynthesis approaches to quality measurement should eliminate such differences in measures of quality, because they require direct auditory matching of stimuli, without reference to internal standards that can be modified by auditory experience. To test this hypothesis, clinicians and naive listeners matched synthetic voice tokens to natural stimuli by adjusting synthesizer parameters of voice quality. No significant differences emerged between groups, suggesting that previously reported group differences are artifacts of traditional quality measurement tasks. Analysis-resynthesis approaches to measuring voice quality perception thus appear to control variability in judgments resulting from differences in internal standards. [Work supported by NIDCD Grant DC01797.]

2pSC14. The effects of speech rate and listening experience on the intelligibility of synthesized speech. Carol McCole (New York City Board of Education, Technology Solutions, District 75, 400 First Ave., New York, NY 10010 and Dept. of Speech, Commun. Sci., and Theatre, St. Johns Univ., Jamaica, NY 11439) and Fredericka Bell-Berti (St. Johns Univ., Jamaica, NY 11439)

Some persons with severe communication disorders are only able to communicate effectively using speech synthesizers, although even the most intelligible synthesis systems (e.g., DynaVox-DECTalk) have limitations. Listener success has been reported to vary with listener age, listener experience with synthesized speech, speech rate, and the presence of pauses between words. This series of experiments has examined the effects of listener age and experience, and speech rate and interword pauses on the perception of synthesized speech. Eighty IEEE-Harvard Sentences were presented to four groups of 12 listeners each [children (9-11 years), teens (14-16 years), young adults (20-25 years), and adults (38-45 years)], in two experiments. In the first experiment (40 sentences) speech rate was varied (105, 135, 165, and 195 wpm); in the second experiment (40 sentences), 7-12 days later, interword pauses occurred in half the sentences. Conditions were counterbalanced; no sentence was presented twice. Preliminary results indicate little effect of speech rate but a substantial effect of experience for the children: they improved substantially