11:20

4aSA9. Intensity maps of systems with complex eigenvalues. Xianhui Li and J. Gregory McDaniel (Dept. of Aerosp. and Mech. Eng., Boston Univ., 110 Cummington St., Boston, MA 02215)

Maps of structural and acoustic intensities have been widely used to understand the dynamics of complex systems with time-harmonic forcing. Identification of the dominant power paths helps designers introduce modifications that control them. For example, damping treatments can be placed to dissipate the maximum power and effectively reduce unwanted vibration. Similarly, high-impedance elements can be configured to block the power flow to sensitive system components. In typical applications, the applied force distributions are chosen to be representative of the expected in situ forces. In this presentation, an extension is described that allows one to construct an intensity map for one mode of a system with complex eigenvalues. This work is motivated by the need to map structural intensity for a squealing mode of an automotive brake system, but it would also be useful in understanding modes of highly damped systems. The proposed extension isolates such modes by choosing a time-harmonic force vector that is parallel to the complex-valued eigenvector, in which case a single mode is isolated. Numerical examples will illustrate the features of this map and contrast it to conventional maps. [Work supported by NSF.]

11:35

4aSA10. Electromechanical realization of impedance matrices. Pierre E. Dupont and Wenyuan Chen (Aerosp. and Mech. Eng., Boston Univ., 110 Cummington St., Boston, MA 02215)

Applications exist at both small and large length scales for which one wishes to design an electromechanical system that reproduces a desired impedance matrix. Such a matrix corresponds to one or more degrees of freedom at several attachment points. The design of MEMS filters for signal processing applications is a small length scale example. At a much larger scale, simplified models of dynamically complex machinery are useful for testing the vibration isolation properties of supporting structures. In the first example, the desired impedance matrix is usually defined mathematically while in the latter, a mobility matrix is obtained by experiment. The realization problem is to obtain an electromechanical system that approximates the desired impedance matrix. Constrained approximation is necessary since the literal realization of idealized filters and complex machinery is often precluded by modal complexity, affecting cost and difficulty of construction, and implementation issues, such as nonideal boundary conditions and the lack of ''sky hooks.'' A two-stage solution to the realization problem is presented that divides the impedance matrix into passive and active components. In the first stage, a reduced-order passive mechanical model is obtained. This model is then modified to incorporate the active behavior. [Work supported by ONR.]

THURSDAY MORNING, 7 JUNE 2001 MONROE ROOM, 8:30 A.M. TO 12:00 NOON

Session 4aSC

Speech Communication: Speech Production Potpourri (Poster Session)

Susan Shaiman, Chair

Department of Communication Science and Disorders, University of Pittsburgh, 4033 Forbes Tower, Pittsburgh, Pennsylvania 15260

Contributed Papers

All posters will be on display from 8:30 a.m. to 12:00 noon. To allow contributors an opportunity to see other posters, contributors of odd-numbered papers will be at their posters from 8:30 a.m. to 10:15 a.m. and contributors of even-numbered papers will be at their posters from 10:15 a.m. to 12:00 noon.

4aSC1. English stress timing and dynamical control of speech timing. Robert Port, David Collins, Adam Leary, Deborah Burleson (Dept. of Linguist., Indiana Univ., Bloomington, IN 47405), and Mafuyu Kitahara (NTT Labs., Atsugi, Japan)

Studies of English speech timing have concluded that, despite earlier claims, English is neither stress-timed nor syllable-timed. This study directly measured context effects on timing depending on prosodic neighborhood, and compared the contribution of any stress-timing or syllable-timing tendency while speech cycling. Ss repeated a phrase to a metronome at varying rates. This complex metronome included high-pitched tones ('beeps') at roughly 1 s with a lower tone ('boop') occurring either 1/2 (2-beat) or 2/3 (3-beat) of the way between beeps. We hypothesize dynamical attractors for stressed syllables at simple harmonic fractions (1/2, 1/3, 2/3) of the phrase cycle. Various texts invite readings with two stresses ('Bite the back') or three stresses ('Bite Bill's back'), and some had perturbing unstressed syllables inserted between stressed ones ('Biting Bill's back'). Perturbing and target vowel onset times were fit with a multiple linear regression equation using time predictions assuming equal stress intervals or equal syllable intervals. The estimated slopes indicate the relative weight of stress versus syllable timing. The weights were greater for stress timing for all subjects, supporting a model of global speech timing where stressed syllable locations have attractors at harmonic fractions, as might be found in a bank of coupled oscillators.

4aSC2. Speech synthesis by mapping articulator movement patterns to a shape-based area function model of the vocal tract. Brad H. Story (Speech and Hearing Sci., Univ. of Arizona, P.O. Box 210071, Tucson, AZ 85721-0071, bstory@u.arizona.edu)

Orthogonal components of tongue and lip displacement data from two speakers in the Univ. of Wisconsin x-ray microbeam database (Westbury, UW–Madison, 1994) were determined with a principal components analysis (PCA). The PCA was performed on steady-state vowels and at the sentence level. For every time frame, the analysis consisted of fitting a cubic spline to four pellet points on the tongue and to modified positions for the incisor pellet and the upper and lower lip pellets. The modifications brought the pellet positions to the level of the airway. The PCA was performed over a collection of frames and showed that the first two (most significant in terms of variance) orthogonal components were similar in shape to those determined from a set of MRI-based vocal tract area functions [Story and Titze, J. Phonetics **26**, 223–260 (1998)]. Next, the coefficients determined from a sentence-level PCA of the microbeam data

were normalized and used as input to an area function model based also on orthogonal shaping components. The result is that articulatory movement patterns from data in the x-ray microbeam database can be transformed to movement patterns of a vocal tract area function to reproduce (synthesize) the original sentence. [Work supported by NIH R01-DC04789-01.]

4aSC3. Sentence-final lengthening in connected text. Caroline L. Smith and Lisa Hogan (Dept. of Linguist., Univ. of New Mexico, Albuquerque, NM 87131-1196, caroline@unm.edu)

Lengthening at the end of a prosodic domain is a robust pattern in English, with larger domains characterized by greater amounts of lengthening. Here we investigate whether this pattern extends above the sentence. Is there more sentence-final lengthening at the end of a paragraph than at the end of a paragraph-internal sentence? Ten recordings were made at weekly intervals of an American English speaker reading extracts from a computer manual, which was chosen because such writing has well-defined topic structure. At the same recording sessions, the speaker also read isolated sentences which were constructed so that each word that was sentence final in the connected text occurred sentence medially in one of the sentences, which were designed to match the presence or absence of a pitch accent on the word in the text. Sentence-final lengthening in the text was gauged by comparing a word's duration in the text to its mean duration across the ten repetitions of the isolated sentences. Very preliminary results suggest that there is more lengthening at the end of a paragraph than in the middle of a paragraph; headings may behave like part of the following paragraph. [Work supported by NSF.]

4aSC4. The influence of speaking rate on spirantization in motor speech disorders. Greg S. Turner (Dept. of Commun. Disord., Central Missouri State Univ., Martin 64, Warrensburg, MO 64093, turner@cmsul.cmsu1.edu)

Spirantization occurs often in the speech of individuals with dysarthria. Impairment of muscle movement can lead to an incomplete articulatory obstruction of the vocal tract during the closure period for the production of stop consonants. Air passes through the narrow constriction associated with the incomplete constriction, resulting in the production of fricative noise during the stop gap. This noise leads to the perception of imprecise articulation. It is hypothesized that the speaking rate at which an individual with dysarthria talks will influence the frequency of spirantization. The slower the speaking rate the more time is allowed for the speaker with dysarthria to achieve a tight constriction during the closure period for stop production, resulting in a reduction of spirantization. The opposite would occur for faster rates. For this experiment, individuals with dysarthria read the Farm Passage at three different speaking rates (hab, slow & fast). From this passage, the production of initial voiceless stop consonants (/p, t & k/) were analyzed for the presence of frication during the closure period. Statistical comparisons were made across speaking rate and place of production. group and individual results will be presented.

4aSC5. Variant frequency in American English flap production. David Patterson and Cynthia M. Connine (Psych. Dept., State Univ. of New York at Binghamton, Binghamton, NY 13902)

This study examined the dominance of flaps as the standard pronunciation of medial /t/ in American English compared to other allophonic variants, namely [t] or glottal stops. A large conversation speech database was utilized to generate statistics about the frequency of occurrence of medial flaps. Results confirmed the dominance of flapping in American English. Interesting effects of morphological complexity and lexical frequency were found to have an effect on the allophonic variant distribution patterns. Morphologically complex words (e.g., waiting) showed a redistribution of variants from flaps to [t] compared to dominant flapping in morphologically simple words (e.g., quota). A similar redistribution of variant production occurred for low-frequency words compared with high-frequency words. The pattern of results was maintained when the morphological analyses were conducted separately for low- and high-frequency words. A second analysis examining vowel length prior to medial /t/ an medial /d/ showed that the vowel preceding medial /d/ tended to be longer, even though both stops were pronounced as a flap. The relevance of the variability in flap occurrence was discussed in relation to rule based phonology and in reference to potential processes in recognizing spoken words.

4aSC6. The relationship between production of suprasegmental speech characteristics and lung volumes in conversational speech. Kate Bunton and Jill Petska (Inst. for Neurogenic Commun. Disord., Univ. of Arizona, P.O. Box 210071, Tucson, AZ 85721, bunton@u.arizona.edu)

''Monopitch'' and ''monoloudness'' are frequent descriptors of speech produced by people with dysarthria, these terms correspond to acoustic findings of flattened $F0$ contours, limited rms variability, and short phrases. Underlying reasons for these production characteristics, however, have not been investigated. The present study was designed to look at the relationship between use of lung volumes in conversational speech and the production of suprasegmental characteristics in healthy speakers versus those with Parkinson disease. Measures of the suprasegmental components of the speech signal included, $F0$ and rms variability, breath group duration, and number of syllables. Measures of starting and stopping lung volumes for each of the breath groups were also obtained. Results indicate a tendency for subjects to alternate a longer breath group, started at a higher lung volume, with exaggerated prosodic characteristics with a much shorter breath group. Although this pattern was seen in the disorder group, the length of their breath group, and $F0$ and rms variability were limited. The disorder group also tended to initiate utterances at lower lung volumes and continue speaking past resting expiratory level. [Work supported by NIDCD DC-01409.]

4aSC7. Coproduction in VCV disyllables produced by children and adults: A comparison of anticipatory and carryover effects. Carole Gelfer (Dept. of Commun. Disord., William Paterson Univ., Wayne, NJ 07470, gelferc@wpunj.edu) and Fredericka Bell-Berti (St. John's Univ., Jamaica, NY 11439)

Previously, we reported spectral data showing similar patterns of coproduction for children and adults in schwa preceding a stop + vowel [C. E. Gelfer and F. Bell-Berti, J. Acoust. Soc. Am. **107**, 2855 (2000)]. The absence of a clear developmental pattern differs from some previous reports of children's speech gestures [e.g., Nittrouer *et al.*, J. Speech Hear. Res. **39**, 379–389 (1996)]. For both groups in our study, the alveolar place blocked the effects of the following vowel, while vowel effects were observed in the context of the bilabial and velar stops. These results also suggested that the gestures associated with a segment are an integrated unit: The lip gesture associated with the vowel seems to be delayed until the lingual gesture associated with the alveolar closure occurs. This study continues our investigation of these patterns and compares the productions of children 4 to 8 years old to those of adults. Here we study carryover as well as anticipatory effects, using VC+schwa and schwa+CV utterances, where V is /i/ or /u/ and C is /p,b,t,d,k,g/. $F2$ measurements taken at various intervals during schwa will be used as an index of these effects and the presence or absence of developmental trends.

4aSC8. Extracting tongue muscle contraction patterns from tagged cine MRI. Maureen Stone (Univ. of Maryland Med. School, 16 S. Eutaw St., Rm. 500, Baltimore, MD 21201), Danielle Dick, Andrew S. Douglas, Guy Shechter (Johns Hopkins Univ., Baltimore, MD 21218), Cengizhan Ozturk (Bogazici Univ., Istanbul, Turkey), and Michael Guttman (Natl. Inst. of Health, NHLBI, Bethesda, MD 20892)

This study presents mechanically modeled 3-D volumetric strains for the tongue during speech for the syllable ''sha.'' Multiplanar tagged cine MRI (tMRI) provided input data for a B-spline, geometry-independent, cardiac tag tracking method, devised for the heart, which has been adapted for the tongue. Three sets of tMRI images with orthogonal tag planes were collected in 10 axial and 5 sagittal slices for 24 consecutive time phases. The sagittal slices were recorded twice, once each with a series of horizontal and vertical tag planes. The axial slices were recorded once with lengthwise (anterior-to-posterior) tag planes. These tag planes reflect deformations in the SI, AP, and RL directions, respectively. Within the tongue we tracked 3-D motion, calculated 3-D strains in each image plane, and reconstructed 3-D deformation for the entire volume. From the model muscle contraction patterns are inferred for genioglossus anterior, verticalis, and transverse. To infer muscle contraction we determined the lines of action for each muscle, and tracked their linear strains in the appropriate planes for all 24 time phases. Results showed that muscle compressions are consistent with expected muscle contractions, and we were able to distinguish between transverse and verticalis activity. [Work supported by NIH/NIDCD Grant No. DC01758.]

4aSC9. Stability of intra- and inter-articulatory timing for contiguous jaw cycles. Susan Shaiman (Dept. of Commun. Sci. and Disord., Univ. of Pittsburgh, 4033 Forbes Tower, Pittsburgh, PA 15260, shaiman@shrs.pitt.edu)

The current study compared how contiguous cycles of jaw movement, composed of different phonetic contexts, were impacted by global changes across the entire utterance and by more local, phonetic changes. Specifically, articulatory kinematics were examined to determine if patterns of intra- and inter-articulatory timing across manipulations of speaking rate were maintained for both jaw cycles, while being reorganized for phonetic changes (i.e., in coda composition) specific to the second jaw cycle. Five normal speakers repeated the syllables /paep/, /paeps/, and /paepst/, embedded in the carrier phrase, ''Now say —- again,'' using slow, normal, and fast speaking rates. Changes in speaking rate impacted the utterance globally, with both jaw cycles evidencing similar patterns of kinematic change. Conversely, changes in coda composition for the second jaw cycle resulted in local changes to that cycle only, without impacting the first cycle. Individual speakers demonstrated distinct, but systematic patterns of intra- and interarticulatory timing as a function of coda composition and speaking rate. While functional groupings of articulators may be broken apart and reconfigured for subsequent movements, global suprasegmental changes result in timing patterns which are consistent across these reorganized functional groupings. [Work supported by CRDF–University of Pittsburgh and NSERC.]

4aSC10. Schwas with and without active gestural control. Iris Smorodinsky (Dept. of French and Italian, Univ. of California, Santa Barbara, CA 93106; Yale Univ.; and Haskins Labs., smorodin@humanitas.ucsb.edu)

This study investigates whether some epenthetic vowels are targetless, that is, whether they can arise from the timing of the surrounding consonants [C. P. Browman and L. Goldstein, Papers in laboratory phonology II: Gesture, segment, prosody, 26–56 (1992)]. Specifically, the difference in targetlessness between past tense and lexical schwas in American English is examined. Articulatory data were collected from three speakers of American English using an electromagnetic midsagittal articulometer. The stimuli included phrases with past tense and lexical schwas embedded in a common environment: for example, ''If cheated even once'' (past tense schwa) and ''If Cheetah'd even known'' (lexical schwa). If the tongue body is assumed to be controlled continuously by the targetful vowels, the tongue body position ''during a schwa'' should not differ significantly from the tongue body position during the preceding vowel in the epenthetic schwa tokens while it would in the lexical schwa tokens. In addition, if the lexical schwas have tongue body gestures associated with them but the past tense schwas do not, a significant interaction between schwa type and vowel context is expected. These results would provide evidence of a difference in targetlessness between the past tense and lexical schwas in American English. [Work supported by NIH.]

4aSC11. The phonetics of stress clash in spontaneous speech. Lesley M. Carmichael (Dept. of Linguist., P.O. Box 354340, Univ. of Washington, Seattle, WA 98195-4340, lesley@u.washington.edu)

This study examines the rhythm rule (RR) in spontaneous speech to determine its acoustic correlates and phonetic robustness in conversational intonation. RR in English is a phonological process that accommodates stress clash. It has been primarily investigated in controlled speech. Both analyses of RR were considered in this study: (1) accent reversal—the relative prominence of key syllables is reversed, (2) accent deletion—the relative prominence of key syllables is neutralized. Two hypotheses were investigated: (1) RR is always indicated by measurable acoustic properties. (2) RR is subject to intonational factors and depends upon the attraction of a pitch accent for realization. Duration, f0, and amplitude were measured on relevant syllables. ToBI labeling was used to indicate pitch accents and phrase boundaries. Duration was the most consistent acoustic cue to stress clash resolution. When the target phrase attracted a pitch accent, duration indicated stress clash resolution by accent reversal. When the target phrase did not attract a pitch accent, f0 and duration indicated accent deletion. Crucially, when the phrases did not attract pitch accents (were not intonationally prominent), stress clash was resolved. This finding provides support for hypothesis (1): RR is pervasive in the acoustic signal independently of intonational factors.

4aSC12. Vocal tract length development: MRI procedures. Houri K. Vorperian (Waisman Ctr., Univ. of Wisconsin–Madison, 1500 Highland Ave., Madison, WI 53705), Cliff M. Kalina, Ray D. Kent, Brian S. Yandell, and Lindell R. Gentry (Univ. of Wisconsin–Madison, Madison, WI)

From infancy to adulthood, vocal tract length increases by about twofold. The purpose of this study is to assess the developmental changes in the various hard and soft tissue structures in the vicinity of the vocal tract that contribute toward its length. Magnetic resonance images (MRI) from children (birth to 6 years) and adults were used since MRI provides detailed visualization of the soft tissues in the oral and pharyngeal regions along with adequate visualizations of related bony and cartilaginous structures. Using previously established measurement procedures (Vorperian *et al.*, 1999), the following structures were measured: lip thickness, hard and soft palate length, tongue length, oro- and naso-pharyngeal length, mandibular length, and position of the hyoid bone and larynx in relation to the nasal spine. Findings will be discussed in terms of: (a) the relative contribution of the various structures toward vocal tract length and how the extent of contribution changes with age; and (b) the relative and relational growth of the different structures. Findings provide normative data on the various vocal tract structures measured; also, they contribute toward understanding the anatomic changes that may be a substrate to speech emergence and development. [Work supported by NIDCD Grant No. R03-DC 4362.]