Session 5aAA

Architectural Acoustics, Noise, and ASA Committee on Standards: Restaurant Acoustics

Klaus Genuit, Cochair
HEAD acoustics GmbH, Ebertstr. 30a, Herzogenrath 52134, Germany

Brigitte Schulte-Fortkamp, Cochair
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Kenneth W. Good, Cochair
Armstrong, 2500 Columbia Ave., Lancaster, PA 17601

Chair's Introduction—8:00

Invited Papers

8:05

5aAA1. Restaurant acoustics—A challenge for consultants. Klaus Genuit (HEAD Acoust. GmbH, Ebertstr. 30a, Herzogenrath, NRW 52134, Germany, Klaus.Genuit@head-acoustics.de)

A good restaurant should be a place where you can enjoy food, drinks, and talking with friends. This means besides the quality of the dishes, wines, etc., the acoustical comfort in the restaurant is an important parameter. But how to describe a good acoustical quality of a restaurant, what are the parameters, how to measure, and how to evaluate the situation? Not only is the level an indicator but others like privacy and speech intelligibility are also indicators. As the overall perception and evaluation of the event inside a restaurant is strongly dependent on context besides measurement and analysis, interviews of the involved people are requested like it is recommended within the new ISO TS 12913-2 standard for soundscape. An overview of different factors influencing the restaurant acoustics and methods exploring the sound will be given.

8:25

5aAA2. What is "typical" restaurant design today? Kenneth W. Good (Armstrong, 2500 Columbia Ave., Lancaster, PA 17601, kwgoodjr@armstrong.com)

More and more patrons and restaurant owners are acknowledging that acoustic comfort contributes to an enjoyable experience. So, what is the "typical" design and the "typical" acoustics of restaurants and similar hospitality spaces today? This paper will explore basic information for over 50 restaurants and hospitality spaces. Included in the data, we will consider room size, ceiling height, surface, and basic room acoustic. This will present a cross-section of the current industry designs and issues that the acoustic community faces today.

8:45

5aAA3. Restaurant acoustics—Unconducted and sometimes unintended orchestrations—An overview. Wade Bray (HEAD Acoust., Inc., 6964 Kensington Rd., Brighton, MI 48116, wbray@headacoustics.com)

The modern restaurant, such as the modern concert hall, is a societal orchestration on many levels including and involving acoustics. The restaurant overlays a business approach, diner tastes, architecture, and other socio-economic factors in superimposed circles of interaction thought to be planned but in action often unanticipated with unwitting consequences. The n-dimensional influences of restaurant acoustics have distinct parallels with the n-dimensional influences of concert hall acoustics. In a concert hall, it is not enough to have architectural beauty, a quiet background and good acoustics in the audience area if onstage acoustics do not support the musicians as individuals in an ensemble. If players must expend concentration on coping instead of elevating unhindered into their art, the quality the audience desires of the music cannot be reached. But if both onstage and audience area acoustics are good, the music soars, audiences keep coming and paying, all participants reap positive rewards, and the organization is successful and self-perpetuating. In this overview, we suggest that the influence of a restaurant's acoustics on its success/satisfaction outcome is perhaps even more complex with more human dimensions and less known than that of the concert hall but that observing and considering these parallels may be beneficial.

9:05

5aAA4. Restaurants part 3: The acoustics of dining spaces. Keely Siebein, Gary W. Siebein, Hyun Paek, Gary Siebein, Marylin Roa, Jennifer R. Miller, and Matthew Vetterick (Siebein Assoc., Inc., 625 NW 60th St., Ste. C, Gainesville, FL 32607, ksiebein@siebeinacoustic.com)

Restaurants are spaces where people gather to eat, talk, share, and spend time. They are also facilities where food is prepared and served to others. Restaurants have garnered much attention over the last several years as having high sound levels with some customers having difficulty in communication among patrons and staff. However, spaces such as cafeterias, dining rooms in country clubs, retirement centers, and hospitals serve similar functions as restaurants and suffer from similar acoustic issues. Acoustic measurements of alpha bar, reverberation time, reflected sound energy, noise reduction, and STI were made in various types of dining spaces that have required acoustic treatment. Data from these types of spaces have been added to the data previously collected at restaurants, to provide general information about the acoustics of dining spaces. The results show that dining spaces can be broken into similar treatment categories, regardless of the specific type of space. The sample of rooms was also analyzed by architectural and interior design style to identify design trends that affect the acoustical metrics in dining spaces.

9:25

5aAA5. An innovative approach in data collection for restaurant soundscape study. W. M. To (Macao Polytechnic Inst., Macao, Macao) and Andy Chung (Macau Instituto de Acústica, Macao, Macao, Macao, ac@smartcitymaker.com)

Crowdsourcing is one of the common approaches in collecting sonic and human perception information for studying restaurant soundscape. However, it has not been easy to find a good reason to motivate people so as to obtain their support continuously in data collection. An innovative approach has been developed and tried in various locations in Asia. This paper presents the initial findings.

9:45–10:00 Break

Contributed Papers

10:00

5aAA6. A restaurant noise study of continuous and transient noise phenomena. Tiffany A. Bixler (Phys. Dept., U.S. Naval Acad., 109 Archwood Ave., Glen Burnie, MD 21061, tiffanybixler7@gmail.com) and Murray S. Korman (Phys. Dept., U.S. Naval Acad., Annapolis, MD)

Two restaurants that the author (Bixler) is familiar with are compared in this noise study. Restaurant 1 is a moderately busy (with varying crowds) sports bar that is considered "Americana." Restaurant 2 is a very busy (always crowded) Texas themed sports bar. Measurements use a RadioShack model 3300099 Digital Sound Level Meter and a SoundMeter X (Version 10.2.2) (application by faberacoustical.com that can be downloaded free from the App Store onto an i-Phone). A professional analysis "Pro tool set" is available and includes a level meter, dosimeter, octave analyzer, and a recorder. These restaurants have interesting areas for studying both continuous and transient noise phenomena. Noise measurement locations include: the dishwasher's sink (sounds of dishes being washed), the surrounding grill area (sounds of cooking food and moving pans), the bar, the main dining area, and the high-top tables near the bar (to measure the rise and fall of sound levels as conversations ensue). Noise measurements include the prep area, the back sink, behind the bar, host stand, foyer, and main seating areas. Transient noise and sound levels averaged (between 15 s and 1 min) will be presented for different times for slow periods, mediums crowds, and full capacity seating.

10:15

5aAA7. Distributions of reverberation time measurements from restaurants of different Layouts. Victoria R. Anderson (Durham School of Architectural Eng. and Construction, Univ. of Nebraska - Lincoln, 4621 A St., Omaha, NE, 68182, Lincoln, NE 68510, vranderson@unomaha.edu), Kieren H. Smith, and Lily M. Wang (Durham School of Architectural Eng. and Construction, Univ. of Nebraska - Lincoln, Omaha, NE, 68182, Lincoln, NE)

The purpose of this research is to determine how reverberation time differs spatially in restaurants with different seating arrangements such as spaces with one main dining room versus spaces with several connected dining areas branching off a main area. The physical layouts of a number of restaurants were spatially recorded, and impulse responses were taken at set interval locations throughout the unoccupied restaurants. Reverberation times have been calculated from the impulse responses and spatially mapped throughout the rooms in order to visually understand the distributions. The average reverberation time and standard deviations in each restaurant are presented and compared to similar data calculated previously for classrooms (Peng *et al*., 2012). Sound levels have also been logged from each restaurant during occupied times, and relationships between sound levels in an area and local reverberation time are explored.

Invited Paper

10:30

5aAA8. Characterization of restaurant soundscapes based on logged sound levels and occupancy measurements. Kieren H. Smith, Victoria R. Anderson, and Lily M. Wang (Durham School of Architectural Eng. and Construction, Peter Kiewit Inst., Univ. of Nebraska-Lincoln, Omaha, NE 68182, kierenhs@gmail.com)

Sound levels in a restaurant depend on a variety of factors including the restaurant's room shape, materials, seating layout, and the levels of ambient and human-produced noise. To better understand the characteristics of restaurant acoustics in real world settings, an *in situ* study has been undertaken in a sampling of sit-down dining venues. Assorted geometric room characteristics, impulse responses, and background noise data were gathered from the spaces. Sound levels were also logged in the restaurants during operating hours simultaneously with occupant count and density using thermal imaging. The gathered data are analyzed to characterize the soundscapes of some existing restaurants. In particular, the research aims to understand how sound levels increase with occupancy and how specific architectural and design features such as seating style and density may contribute to experienced sound levels.

10:50–11:10 Panel Discussion

Session 5aAB

Animal Bioacoustics, Signal Processing in Acoustics, Acoustical Oceanography, Speech Communication, and Underwater Acoustics: Understanding Animal Song

John Hildebrand, Chair
Scripps Institution of Oceanography, University of California San Diego, Mail Code 0205, La Jolla, CA 92093

Invited Papers

8:00

5aAB1. The characteristics of song: An overview for marine mammals. John Hildebrand (Scripps Inst. of Oceanogr., Univ. of California San Diego, UCSD-0205, La Jolla, CA 92093, jhildebrand@ucsd.edu)

Animal song is often considered to have the following characteristics: (1) produced by males, (2) territorial—related to ownership of an area, (3) stereotyped, (4) seasonally produced, and (5) involved in reproductive displays. The extent to which marine mammals fit these criteria is considered for a variety of species. The occurrence of female song and the lack of clear territoriality are examples that challenge the above model for sexual-selection of singers. Likewise, the factors driving long-term trends in song are not well understood. New perspectives are needed to understand the mechanisms driving marine mammal song.

8:25

5aAB2. Evidence of synchronous chorusing in North Atlantic minke whales (*Balaenoptera acutorostrata*. Michael A. Stocker (Ocean Conservation Res., P.O. Box 559, Lagunitas, CA 94938, mstocker@OCR.org)

Many arthropods are known to chorus acoustically. Some families such as the *Gryllidae* are known to synchronize their chirping, and other families such as the *Cicadidae* are known to buzz together or pulse in groups. In the *Gryllidae,* synchronization is facilitated by way of corollary discharge that "blanks" the auditory nerve concurrent to stridulation syllables. This permits the individual animal to "not hear" itself while chirping and to hear nearby conspecifics if they are not in sync. Thus, when animals are synchronized, none of them hear anything, unless one falls or phases out of sync. There are many conjectures as to why they synchronize. It is clear that in doing so, they establish an acoustic community. The larger sound-field also ambiguates the location of individual animals to potential predators. There is some evidence that conspecific communication occurs within the chorus which may convey local conditions (such as the presence of a predator) to the acoustic community. Many rorquals (blue, fin, sei, Brydes, and minke whales) pulse in the low and infrasonic frequency ranges. This paper will present and evaluate recorded evidence which might suggest that minke whales may synchronize their pulsing with others—potentially forming an acoustic community with conspecifics.

8:50

5aAB3. Song structure and sex-specific features in the indris. Marco Gamba, Daria Valente, Chiara De Gregorio, Anna Zanoli (Life Sci. and Systems Biology, Univ. of Torino, Via Accademia Albertina 13, Torino 10123, Italy, marco.gamba@unito.it), Rose Marie Randrianarison (Life Sci. and Systems Biology, Univ. Of Torino, Antananarivo, Madagascar), Valeria Torti, and Cristina Giacoma (Life Sci. and Systems Biology, Univ. of Torino, Torino, Italy)

In the dense tropical rainforests of Madagascar, visual communication is impeded by obstacles. Lemurs use scent marking to communicate at a short distance and loud calls to communicate at a long range. The Indri (Indri indri) is a diurnal primate that emits choruses of three distinct types. The song types are essential in advertising position within the group territory, in deciding the sorts of aggressive group encounters, and in maintaining cohesion between animals dispersed during feeding. A detailed examination of the advertisement songs showed that three main parts constitute them. The last, most consistent of these parts, showed phrases consisting of units emitted with a descending frequency. The rhythm of these units changed significantly between phrases of different durations and the sexes. We also found that the unit structure may provide conspecifics with information on the individual identity of the emitter and that male songs, but not female's, are more similar to those of their parent of the same sex than to other indris. The song of the indris is an effective way to transfer information at a long distance and may transmit sex and individual identity information.

9:15

5aAB4. Mosquito hearing is the most sensitive among arthropods—But is the sound level of a male swarm loud enough to be picked up by the female's particle-velocity sensor? Lionel Feugère (MIVEGEC, IRD, CNRS, Univ. Montpellier, Montpellier, France and Natural Resources Inst., Univ. of Greenwich, Central Ave., Chatham Maritime ME4 4TB, United Kingdom, lionel.feugere@ird.fr), Gabriella Gibson (Natural Resources Inst., Univ. of Greenwich, Chatham, Kent, United Kingdom), and Olivier Roux (MIVEGEC, IRD, CNRS, Univ. Montpellier, Montpellier, France)

Males of many mosquito species aggregate in station-keeping swarms, waiting for the arrival of conspecific females to mate with. We test whether audition could be used by a female to locate male swarms and to assess whether the males are conspecific. The sound level resulting from thousands of wing flaps could be loud enough to be heard at a long range (~1 m) via the antennal flagellum (particle velocity sensor, primarily designed for close-range communication). A mosquito hears a conspecific by adjusting its own wing-beat frequency so that the difference tone between its own and the opposite-sex frequencies falls into a narrow band to which the auditory organ is tuned. Indeed, the antennal flagella produce distortion products resulting in difference tones of the nearby soundscape. Swarms of males were recorded and played-back to females in a 2-m-sided flight chamber. The natural sounds of the males of two species (*Anopheles coluzzii* and *A. gambiae*) and related synthetic sounds were played at different sound levels to individual free-flying *A. coluzzii* females. The mosquitoes' responses were investigated by analysing changes in three-dimensional-tracked flight trajectories and wing-beat frequencies. The results show that (1) females do respond to the sound of swarming males, (2) a qualitative difference between female and male behaviour, (3) a quantitative effect of the sound stimulus of conspecific males, and (4) verification of previous results suggesting the importance of the first harmonic of their wing beats in mosquito acoustic communication.

9:30

5aAB5. Deep learning for underwater noise classification. Johnny L. Chen, Sarah Nguyen, Jason M. Trader, Andrew Moore (Appl. Res. in Acoust., LLC, 209 N. Commerce St., Ste 300, Culpeper, VA 22701-2780, johnny.chen@ariacoustics.com), and Jason E. Summers (Appl. Res. in Acoust., LLC, Washington, District of Columbia)

Deep-learning models have surpassed many computer-vision benchmarks and groups such as Google have begun to investigate similar methods for understanding underwater data. Understanding underwater soundscapes is critical to many applications such as assessing the impacts of anthropogenic noise on sea life and monitoring the health and biodiversity of the ocean. In this work, we present a computer-vision approach for classifying audio signals to distinguish whale sounds—especially, vocalizations from mysticetes—from other sources of sound in the underwater soundscape, such as ships. This is a challenging problem due to wide variation in ambient background noise, sensor configuration and properties, and whale vocalization patterns within and across species. Here, we adapt deep convolutional neural networks (CNN) to analyze spectral patterns of common noise sources and demonstrate robust performance on a dataset of ambient noise derived from multiple open-source databases including whale vocalizations from eight species and shipping noise from over ten platforms observed across multiple environments with a variety of sensors. Performance of the network is characterized in terms of classification accuracy and generalizability as a function of CNN hyperparameters and training architecture. With a CNN trained from scratch, we analyze the learned features of the classification decisions of the network by adapting several visualization techniques from the computer-vision domain.

FRIDAY MORNING, 17 MAY 2019 NUNN, 8:00 A.M. TO 11:30 A.M.

Session 5aBA

Biomedical Acoustics: General Topics in Biomedical Acoustics III

Alfred C. Yu, Cochair
University of Waterloo, EIT 4125, Waterloo, ON N2L 3G1, Canada

Julianna C. Simon, Cochair
Graduate Program in Acoustics, Pennsylvania State University, 201E Applied Sciences Building, University Park, PA 16802

Contributed Papers

8:00

5aBA1. Electroacoustic tomography system using ultra-short electric filed excitation source induced acoustic signals. Ali Zarafshani (Eng. and Design, Easter Washington Univ., 319 G Computing and Eng. Bldg., Cheney, WA 99004, azarafshani@ewu.edu), Bin Zheng, and Liangzhong Xiang (Medical Imaging, School of Elec. and Comput. Eng., Univ. of Oklahoma, Norman, OK)

Application of an ultra-short, high-intensive electric field has been gaining momentum to many advanced clinical techniques for treating deep-seated tumors based on the electroporation technique. Real-time monitoring is essential for such high impact clinical techniques. Real-time monitoring of electroporation-based medical interventions could be based on the electroacoustic tomography, where the electric field applied for the electroporation process leads to induce acoustic signals based on the flow of electrical current inside the target tissue and then the effects of rising temperature on acoustic pressure. A μs-to-ns high-voltage electric-pulse excitation source is connected to two electrodes separated by a distance of 200μm, where mounted into the conductive media to simulate tissue. An unfocused ultrasound transducer with a central frequency of 500 kHz is used to acquire real-time acoustic signals induced by the electric field. Various conductive media were studied using this pulsed excitation source to induce corresponding acoustic signals, forming two-dimensional tomography images. Results indicate the feasibility of the enhancing the electroacoustic

tomography system that used the high-voltage, ultra-short pulsed excitation source for clinical processes as an imaging guidance to real-time, *in situ* monitoring for the electroporation-based techniques.

8:15

5aBA2. Evaluation of a passive super-resolution beamforming technique for B-mode imaging. Anil Agarwal and Michael Oelze (Univ. of Illinois at Urbana-Champaign, 405 N Mathews Ave., Urbana, IL 61801, aragarw2@illinois.edu)

Improving spatial resolution of ultrasonic scanners would allow improved imaging performance. A lateral resolution is limited by diffraction and the width of the beam used to interrogate the medium. Techniques for improving the lateral resolution beyond the diffraction limit have utilized dilute concentrations of microbubbles (MBs) to localize MB locations. These approaches enable the mapping of microvasculature but do not allow improvements in general B-mode imaging. Null Subtraction Imaging (NSI) is a passive nonlinear image processing scheme that constructs images from the nulls in the beam pattern of an array rather than the main lobe. In NSI, envelopes reconstructed with different apodizations are combined to form an image with an improved apparent lateral resolution. NSI is computationally efficient compared to adaptive beamforming approaches and does not need MBs. Experiments have demonstrated improvements in a resolution of over 100 times compared to conventional delay-and-sum beamforming with no apodization. Engineering trade-offs associated with combining different apodization functions, angular steering, and interpolation were assessed using the NSI technique. The utilization of the NSI for specific imaging tasks was also evaluated. The results of the study suggest that NSI could provide improved performance for the detection of small microcalcifications, which has application in detecting and identifying malignant cancers.

8:30

5aBA3. Tissue Doppler imaging to detect muscle fatigue. Joseph Majdi and Siddartha Sikdar (George Mason Univ., 4400 University Dr., Fairfax, VA 22030, jmajdi2@masonlive.gmu.edu)

Functional electrical stimulation (FES) is often used for rehabilitation in movement disorders and in assistive devices such as exoskeletons. However, FES can rapidly cause muscle fatigue, which limits the induced force production. At present, there exists no reliable, real time indicator for FES-induced muscle fatigue. We believe that functional muscle physiology associated with muscle fatigue can be inferred from ultrasound imaging. In this study, we utilized tissue Doppler imaging (TDI) to quantify FES-induced twitch responses in the gastrocnemius muscle, at baseline and after inducing fatigue through repeated voluntary isometric contractions. We estimated muscle velocities using M-mode TDI to quantify differences in the twitch response before and after fatigue. Preliminary results indicate that fatigue induces a higher muscle acceleration during twitch, and the muscle contracts for a longer duration. These results could potentially be used as a real-time indicator for muscle fatigue. We are investigating the use of such a system integrated into an external hybrid walking exoskeleton that can switch from FES-induced force generation to external motors for force generation once the muscle fatigues. Furthermore, it may be possible to replace TDI imaging with a wearable single-element continuous wave Doppler instrument for these measurements, reducing computational complexity and power requirements.

8:45

5aBA4. Interpretability and generalizability of a one-dimensional convolutional neural network method for hepatic steatosis characterization. Aiguo Han (BioAcoust. Res. Lab., Dept. of Elec. and Comput. Eng., Univ. of Illinois at Urbana-Champaign, 306 North Wright St., Urbana, IL 61801, han51@uiuc.edu), Yingzhen N. Zhang, Michael P. Andre (Liver Imaging Group, Dept. of Radiology, Univ. of California at San Diego, La Jolla, CA), Rohit Loomba (NAFLD Res. Ctr., Div. of Gastroenterology, Dept. of Medicine, Univ. of California at San Diego, La Jolla, CA), John W. Erdman (Dept. of Food Sci. and Human Nutrition, Univ. of Illinois at Urbana-Champaign, Urbana, IL), Claude B. Sirlin (Liver Imaging Group, Dept. of Radiology, Univ. of California at San Diego, La Jolla, CA), and W. D. O'Brien Jr. (BioAcoust. Res. Lab., Dept. of Elec. and Comput. Eng., Univ. of Illinois at Urbana-Champaign, Urbana, IL)

Nonalcoholic fatty liver disease (NAFLD) affects 25% of the population globally. We developed a one-dimensional convolutional neural network (1-D CNN) method for the ultrasound tissue characterization using radio-frequency (RF) data and demonstrated its potential for the liver fat classification and quantification. We investigate herein the interpretability and generalizability of the method to understand why it works, and whether the performance is affected by settings, transducers, and platforms. We studied under various conditions the performances of 1-D CNN for predicting steatosis using magnetic resonance imaging-estimated proton density fat fraction (MRI-PDFF) as reference (steatosis: PDFF $>$ 5%). Three datasets were used, each containing ultrasound RF data acquired from adults and same-day MRI-PDFF estimates: (1) 200 normal and NAFLD participants scanned using the Siemens S2000 ultrasound system with the 4C1 transducer (1–4 MHz); (2) 87 participants with known/suspected NAFLD scanned using Siemens S3000 with the 4C1 and/or 6C1HD transducers (1.5–6 MHz); and (3) 46 participants with known/suspected NAFLD scanned using GE Logiq e9 with the C1-6 transducer (1–6 MHz). The 1-D CNN method is generalizable among various instrumentation settings (e.g., focal depth, time gain compensation), betweentransducers of similar frequencies, between platforms, but not between the fundamental and tissue harmonic image modes. [Work supported by R01DK106419.]

9:00

5aBA5. A study on the improvement of a brain concentration using acoustic characteristics of sound. Seonggeon Bae (Div. of Comput. Media Information Eng., Kangnam Univ., 40, Kangnam-ro, Giheong-gu, Youngin-si 446-702, Gyeonggi-do, South Korea, sgbae@kangnam.ac.kr) and Myungjin bae (TeleCommun. and Information, Soongsil Univ., Seoul, Korea)

It has been studied variously using acoustic features. The purpose of this study is to investigate whether the characteristics of acoustic signals improve the brain concentration. Especially, the phenomenon that occurs in a tedious and repetitive environment is analyzed by using acoustic characteristics of sound. This characteristic was measured by 20 persons in general, and the concentration of brain was compared and analyzed.

9:15

5aBA6. On a recovery of hoarseness by reflecting the amplified voice. Myungsook Kim and Myungjin Bae (Commun. Eng., Soongsil Univ., Sangdo-ro 369, Seoul 06978, South Korea, kimm@ssu.ac.kr)

If you make a loud voice and lecture with a high voice tone, you usually get a hoarse voice. The voice is generated by ejecting air pressure from the lungs through the folder of the vocal cords to create a tonal tone and resonance in the vocal tract. In this paper, we propose a new loudspeaker amplification tone that induces a hoarse voice when loudly voiced for a long time. In the proposed method, when the hoarseness was eliminated, the average sound pressure level was recovered to +5.2 dB and the spectrum in the high frequency range was improved by the average magnitude level of +12.6 dB. It is confirmed that the clarity of vocalization is more than usual in the measurement of vocal clarity.

9:30

5aBA7. Loudness growth as a function of presentation method: Comparison of normal hearing children with children using cochlear implants. Shubha Tak and Asha Yathiraj (Dept. of Audiol., All India Inst. of Speech and Hearing, Manasagangothri, Mysore, Karnataka 570006, India, shubha_tak@yahoo.co.in)

The loudness of signals is altered in listening devices used by individuals with hearing loss, where soft sounds are made loud and loud sounds made soft. It is speculated that loudness growth would be affected in those using such listening devices. The study aimed to compare the effect of order of intensity presentation on loudness growth in typically developing children and children using monaural cochlear implants. Loudness growth of 3 warble-tones and 3 vowels were examined in 20 typically developing children and 17 children using cochlear implants. The intensity of the stimuli was varied randomly and sequentially. The children rated the loudness of the stimuli on a six-point rating-scale. Only 10 of the 17 children using cochlear implants gave valid loudness growth responses. These 10 children demonstrated no significant difference between the random and the sequential presentation for most of the stimuli. In general, the typically developing children exhibited a significant difference for the extremes in the loudness-growth scale (very soft and very loud). Loudness growth was similar across the methods and participant groups. Thus, a large number of children using cochlear implants are unable to give reliable loudness-growth responses. Those who have a loudness growth perform similar to the typically developing children.

9:45

5aBA8. Egg white-based ultrasound blood mimicking phantom. Yunbo Liu, Brady Connors, Monica Abboud, and Subha Maruvada (FDA, 10903 New Hampshire Ave., WO62RM2126, Silver Spring, MD 20993, yunbo.liu@fda.hhs.gov)

An egg white-based blood mimicking fluid (BMF) was developed and characterized as a blood coagulation surrogate for the acoustical and thermal evaluation of therapeutic ultrasound, especially high intensity focused ultrasound (HIFU) devices. Physical properties, including coagulation temperature, frequency-dependent attenuation, sound speed, thermal conductivity, and thermal diffusivity, were measured as a function of temperature (20–95 ^{o}C). The fluid viscosity was quantified at room and body temperature. With the addition of Nylon particles in the solution, the backscattering coefficient of the BMF was measured and compared before and after a complete thermal coagulation for diagnostic imaging purpose. For a 30 s thermal exposure, the egg white-based BMF (3 mm thickness) started to denature at 65 ^{o}C and coagulate into an elastic gel at 85 ^{o}C. The coagulation temperature can be lowered by adding a small amount of the acid solution to the BMF. HIFU exposure on the BMF was conducted using a flow loop phantom system to simulate and understand the HIFU ablation process and coagulation dynamics. These blood mimicking properties make this egg white-based ultrasound blood phantom a potential tool for pre-clinical bench testing of medical ultrasound devices.

10:00–10:15 Break

10:15

5aBA9. Renal volume reconstruction using free-hand ultrasound scans. Alex Benjamin (Mech. Eng., MIT, 550 Memorial Dr., Apartment 21D-2, Cambridge, MA 02139, arb93@mit.edu), Melinda Chen (Health Sci. and Technol., MIT, Cambridge, MA), Qian Li (Radiology, Massachusetts General Hospital, Boston, MA), Carolina A. Carrascal, Hua Xie (Philips USA, Cambridge, MA), Anthony Samir (Radiology, Massachusetts General Hospital, Boston, MA), and Brian Anthony (Mech. Eng., MIT, Cambridge, MA)

Kidney volume is a predictor of kidney function or the number of surviving nephrons; as such, it is a valuable biomarker in tracking the onset and progression of chronic kidney disease (CKD). Existing techniques to measure renal volumes [CT, MRI, three-dimensional (3D) ultrasound] are limited by high cost, long scan times, and low portability. To overcome these limitations, we propose a real-time, low-cost solution for estimating renal volumes using free-hand ultrasound scans. The method involves an Intel RealSense D415 camera mounted on a conventional one-dimensional ultrasound probe; RGB-D SLAM is used to localize the probe in free space. The acquired two-dimensional images are manually segmented by trained clinicians and combined with their corresponding poses to form a 3D volume. The method was tested on *ex vivo* sheep kidneys embedded in gelatin phantoms. Three different scanning protocols were tested: transverse linear scan (TL), transverse fan scan (TF), and longitudinal fan scan (LF). Ultrasound measured renal volumes were compared to those obtained using the water displacement (WD) method; TL = 66.2 ml, LF = 58.3 ml, TF = 53.3 ml, and WD = 66.6 ml. Further investigation includes automating kidney segmentation, accounting for patient motion, and *in vivo* validation.

10:30

5aBA10. Etiology of the color Doppler twinkling artifact on kidney stones. Scott A. Zinck (Acoust., The Penn State Univ., 201E Appl. Sci. Bldg., University Park, PA 16802, 19scottz@gmail.com)

Rapid Doppler shifts highlight some kidney stones with a rapid change in color in ultrasound imaging which is called the "twinkling artifact." Many hypotheses exist to describe the mechanism of twinkling, including the hypothesis that microbubbles are stabilized in crevices on the surface of kidney stones. The objective is to evaluate the distribution of stable microbubbles on kidney stone surfaces with humidity-controlled scanning electron microscopy (ESEM) and determine whether any sub-surface characteristics as assessed with micro-computed tomography (μCT) may contribute to twinkling. A Verasonics® research ultrasound system with the Verasonics L22-14 and Philips/ATL L7-4 and C5-2 transducers quantified twinkling. Results show a correlation between voids within kidney stones and the locations of twinkling on the stone surface. These voids had a calculated free-field Minneart resonant frequency of 3–9 MHz depending on the size. ESEM revealed that surfaces that twinkled had more crevices with radii corresponding to bubbles with a free-field resonant frequency of 3–7 MHz. These results suggest that internal voids and surface crevices contribute to the twinkling artifact on kidney stones.

10:45

5aBA11. The effect of crystal chemical composition on the color Doppler ultrasound twinkling artifact. Eric Rokni, Scott A. Zinck, and Julianna C. Simon (Penn State Univ., 201 Appl. Sci. Bldg., University Park, PA 16802, ezr144@psu.edu)

The color Doppler ultrasound twinkling artifact, or localized areas of rapid color shifts, has been used to aid in the diagnosis of kidney stones. Gallstones and some atherosclerotic plaques have also been shown to twinkle, suggesting that crystals, regardless of chemical composition, may harbor the stable microbubbles that are hypothesized to cause twinkling. Here, uric acid, cholesterol, and calcium phosphate crystals, which are often present in sites of pathological biomineralization, were grown in the lab using previously developed techniques and imaged with the Verasonics® research ultrasound system using Philips/ATL P4-2 and Verasonics L22-14 transducers. The magnitude of the Doppler signals was quantified and compared amongst the three crystal chemical compositions. Preliminary results show that all three crystal types displayed twinkling with the strongest magnitude appearing in the cholesterol crystals. These results suggest that twinkling is

very sensitive in the presence of crystals regardless of the chemical composition. Future work will explore the use of histotripsy to mechanically fractionate crystals as a novel treatment for pathological biomineralization.

11:00

5aBA12. Introducing Feelix, a digital stethoscope incorporating active noise control and automatic detection of lung sound abnormalities. Ellington West, Ian McLane (Sonavi Labs, 1100 Wicomico Rd., Ste. 600, Baltimore, MD 21230, ellington@sonavilabs.com), Daniel McLane (Phase Margin, Chatsworth, CA), Dimitra Emmanouilidou (Microsoft Res., Seattle, WA), Mounya Elhilali, James E. West (Elec. and Comput. Eng., Johns Hopkins Univ., Baltimore, MD), Arthur Ward, Ilene Busch-Vishniac (Sonavi Labs, Baltimore, MD), Jaishree McLane (Sonavi Labs, Chatsworth, California), and Brandon Dottin-Haley (Sonavi Labs, Baltimore, MD)

Pneumonia is the top disease killer of children under the age of 5 worldwide, and while the definitive diagnosis of pneumonia typically is made with x-rays, only 5% of the world's population has ready access to radiographic equipment. To address this problem, Sonavi Labs has introduced the Feelix line, a line of digital stethoscopes focused on abnormal lung sound detection. Compared to traditional, mechanical stethoscopes, the Feelix line offers three advantages: reduced sensitivity to placement of the sensing head, active noise cancellation, and automatic detection of lung sound abnormalities using an algorithm that incorporates machine learning. This new line of digital stethoscopes is appropriate for under-resourced regions of the world, for noisy clinics, and for medical professionals who wish to improve their ability to hear lung sounds. Using this line of digital stethoscopes is preferable to alternative methods that are under study, such as lung ultrasound, as its use is entirely noninvasive and its cost is a fraction of that of x-ray machines or ultrasound imagers.

11:15

5aBA13. Ultrasonography education in the first medical-engineering based college. Olivia Coiado (Carle Illinois College of Medicine, Univ. of Illinois at Urbana-Champaign, 1914 Max Run Dr., Champaign, IL 61822-3449, oliviacoiado@hotmail.com)

This work presents an ultrasonography laboratory practice for the first year medical students of Carle Illinois College of Medicine. Carle Illinois is the first college of medicine in the nation designed at the intersection of engineering and medicine. The curriculum, which integrates basic and clinical sciences with engineering and innovation, includes activities for students to navigate through a guided ultrasound practice. In the individual session, students were introduced to an ultrasound machine (Sonosite Edge, FUJIFILM SonoSite, Inc., Bothell, WA) and discussed the ultrasound principles. As preparation for the session, students received a guide where they answered a few questions. The guided practice consisted of describing the parts of a basic ultrasound machine. Students explained ultrasound principles, such as the relationship between frequency and wavelength, different ultrasound imaging modes and types of ultrasound transducers, frequency of ultrasound transducer for diagnosis and therapy, and the continuous Doppler mode. In the end, students had the opportunity to scan the carotid artery and analyze the ultrasound principles discussed. After the guided session, students were allowed to perform scans on their own. The students appreciated the hand-on experiences gained by participation in the ultrasonography-guided session.

FRIDAY MORNING, 17 MAY 2019 JONES, 8:15 A.M. TO 12:00 NOON

Session 5aPA

Physical Acoustics: General Topics in Physical Acoustics II

Kyle S. Spratt, Cochair
Applied Research Laboratories, The University of Texas at Austin, Austin, TX 78713

Kevin M. Lee, Cochair
Applied Research Laboratories, The University of Texas at Austin, 10000 Burnet Road, Austin, TX 78758

Contributed Papers

8:15

5aPA1. Sound speed measurements in Kentucky bourbon whiskey. Stanley A. Cheyne (Dept. of Phys. & Astronomy, Hampden-Sydney College, Hampden-Sydney, VA 23943, scheyne@hsc.edu)

Kentucky is home to most of the bourbon whiskeys sold world wide. Sound speed measurements were made in a number of Kentucky bourbon whiskeys. Results of a variety of whiskeys, some having different alcohol content,s using a time-of-flight technique will be presented. In addition, phase speed measurements in impedance tubes using a transfer function technique will be presented. Experimental results will be compared to what is expected in a water/ethanol mixture.

8:30

5aPA2. Acoustic and dynamic characterization of wooden baseball bats. Kenneth A. Pestka II and Derek E. Holmberg (Chemistry and Phys., Longwood Univ., 201 High St., Farmville, VA 23909, pestkaka@longwood.edu)

We will present the results of several experiments used to characterize the properties and performance of multiple baseball bats composed of four different species of wood including soft maple, hard maple, birch, and ash. Resonant ultrasound spectroscopy was used in an effort to obtain the complete orthotropic tensor of the different wood species. In addition, ultrasonic pulse-echo measurements and dynamic impulse time-of-flight

measurements were performed to obtain longitudinal sound speeds, which in combination with bat geometry, mass, and density enabled the determination of the longitudinal Young's moduli. Bat performance was then experimentally determined via a newly developed non-destructive impact method. The physical acoustic parameters that most significantly correlated with optimum bat performance will also be presented.

8:45

5aPA3. Spontaneous thermokinetic amplitude modulation in the "burning wire" lecture demonstration. Steven L. Garrett (Laboratoire d'Acoustique, Le Mans Université, 151 Sycamore Dr., State College, PA 16801, sxg185@psu.edu) and Guillaume Penelet (Laboratoire d'Acoustique, Le Mans Université, Le Mans, France)

A thin nichrome wire that is tensioned by a mass and driven by an alternating electrical current, with a magnet placed along the wire's length, provides a popular lecture demonstration. Due to the convective cooling of the portions of the wire moving with the greatest velocity, in a darkened room, only the regions near the velocity nodes will be visible due to the orange glow of the heated wire. The thermal expansion coefficient of the wire forces the tensioning mass to change its height as temperature changes. By adiabatic invariance, the changes in the mass's elevation cause the natural frequency to be shifted. Competition between the thermal inertia of the wire and the convective heat transfer coefficient introduces an exponential thermal relaxation time so that the amplitude of vibration is dependent on the ratio of the constant drive frequency to the changing resonance frequency at an earlier (retarded) time. These thermal and kinetic effects are incorporated into three coupled nonlinear ordinary differential equations that are separated by the method of multiple time scales and are solved numerically, reproducing both the spontaneous appearance of stable periodic amplitude modulation and the hysteretic behavior observed with the increasing or decreasing drive frequency.

9:00

5aPA4. Performance analysis of a looped travelling-wave thermoacoustic engine with phase-change. Rui Yang, Avshalom Offner, Avishai Meir, and Guy Z. Ramon (Nancy and Stephen Grand Technion Energy Program and Dept. of Civil & Environ. Eng., Faculty of Civil and Environ. Eng., Technion-Israel Inst. of Technol. Haifa 3200003, Israel, rui.yang@campus.technion.ac.il)

Traditional thermoacoustic engines using conduction-driven, sensible heat transfer are unable to utilize low-grade thermal energy efficiently. Recently, it has been demonstrated that a phase-change thermoacoustic engine can initiate oscillations at a very low temperature difference; however, the steady-stage performance has yet to be extensively studied. In this work, a phase-change thermoacoustic engine with a looped resonator was simulated, based on a linear phase-change thermoacoustic theory. A binary gas mixture consisting of an inert gas and a condensable component was adopted as the working fluid. We numerically investigated the distributions of pressure, volumetric velocity, and acoustic power in the system. We also examined the steady-state performance (characterized by the pressure amplitude, acoustic power, and thermal efficiency) of the system under different mean pressures and temperature differences. The results show that the phase-change thermoacoustic engine can be driven by very low temperature differences (< 50 K) much more efficiently than its dry equivalent (i.e., the same system but without the condensable component). The findings demonstrate the promising potential of generating acoustic power through low-grade heat recovery, which can then be converted into electricity and cooling.

9:15

5aPA5. Measuring the transmission coefficient of a steel plate using an angular spectrum approach. Kyle S. Spratt, Benjamin C. Treweek, Kevin M. Lee, Michael R. Haberman, and Mark F. Hamilton (Appl. Res. Labs., The Univ. of Texas at Austin, Austin, TX 78758, sprattkyle@gmail.com)

Ultrasonic measurements were performed on a thin steel plate submerged in water in order to obtain the plane-wave transmission coefficient as a function of angle and frequency. An angular spectrum approach was utilized wherein the acoustic field parallel to the plate was scanned with sufficient spatial accuracy to obtain a frequency-wavenumber description of the transmitted field, representing an expansion of the field into time-harmonic plane waves propagating within a range of angles. Isotropy of the plate material and symmetry of the measurement configuration allowed for a vast reduction of the number of scan points required in order to obtain the transmitted angular spectrum. Once the transmitted acoustic data is acquired, the specific method of windowing the data in space and time can have a drastic effect on the resulting angular spectrum. With sufficient care, a broadband estimation of the transmission coefficient with a high angular resolution is obtained. Finally, inverse methods were utilized in order to estimate the thickness and material properties of the plate using the measured transmission coefficient data. [Work supported by ONR.]

9:30

5aPA6. Generating ultrasonic acoustic holograms with circular arrays. Paul T. Johnson (Phys., Illinois Wesleyan Univ., 201 E Beecher St., Bloomington, IL 61701, pjohnso3@iwu.edu)

Acoustic holograms are formed by interfering multiple sonic sources of identical frequency and differing phase. By using ultrasonic transducers, three-dimensional printed arrays, and an iterative approximation algorithm, it is possible to computer generate holographic arrays at 40 kHz in different configurations. By using circular arrays, I am able to explore vortex generation in an ultrasonic with a cost-effective desktop setup. These holograms can be measured and plotted using another transceiver. I also am able to make predictions about how to best optimize the designs for a circular array. This research opens up questions to be explored with even more powerful setups.

9:45

5aPA7. Photoacoustic harmony: Using musical concepts to study mixed gases through PA spectroscopy. Trevor Paratore and Han Jung Park (Chemistry, Univ. of Tennessee at Chattanooga, 615 McCallie Ave., Chattanooga, TN 37403, hanjung-park@utc.edu)

Photoacoustic Spectroscopy was applied to study the intensity of musical notes in harmony created by the photoacoustic signals of ethylene (C_2H_4) and sulfur hexafluoride (SF_6) gases. Two CO_2 lasers with a wavelength of 10.6 μm were modulated using two separate mechanical choppers. It was observed that musical notes with a frequency approximately that of the fundamental frequency of the resonator had higher intensity peaks than those further away. To equilibrate the intensities of these notes for fuller tones in the musical chords of interest, a second resonator, sulfur hexafluoride, having vastly different resonance properties from ethylene, was added to the gas cell. It was observed that this only moderately affected the outcome for the overall tone of the chords of interest. However, as expected, sulfur hexafluoride offered a more dynamic range of tones due to its large variance in resonance frequency with concentration.

10:00–10:15 Break

10:15

5aPA8. High temperature dependent elastic properties of single crystalline SnSe. Ashoka Karunarathne, Josh R. Gladden (Phys. and Astronomy & NCPA, Univ. of Mississippi, 145 Hill Dr., University, MS 38677, atholang@go.olemiss.edu), and Gautam Priyadarshan (National Ctr. for Physical Acoust., Univ. of Mississippi, University, MS)

In recent years, single crystalline SnSe has been widely studied as a thermoelectric material which exhibits a high thermoelectric figure of merit ($ZT \sim 2.6$ at $T > 900$ K). The efficiency has been enhanced due to the significantly low thermal conductivity, arising from the strong lattice anharmonicity of the layered orthorhombic crystal structure. A study of the thermoelastic properties of single crystalline SnSe is essential to gain a better understanding of the lattice anharmonicity and the low thermal conductivity. The highly anisotropic orthorhombic crystal structure of SnSe results in nine independent elastic constants. This work seeks to investigate the temperature dependent elastic constants of single crystalline SnSe, using

resonant ultrasound spectroscopic (RUS). Here, we report the experimentally observed elastic constants and their variation at elevated temperature from room temperature to ~775 K. The temperature dependent elastic and thermal properties have been derived from the elastic constants and compared to independent heat capacity data.

10:30

5aPA9. High temperature resonance ultrasound spectroscopy studies of single crystal minerals. Sumudu P. Tennakoon and Mainak Mookherjee (Earth, Ocean and Atmospheric Sci., Florida State Univ., Tallahassee, FL 32306, stennakoon@fsu.edu)

Elasticity of mineral phases at temperature and pressure conditions relevant to earth interior is essential for constraining the composition and the dynamics of the deep Earth. To constrain the temperature dependence of elasticity of hydrous minerals relevant to the earth's subduction zones, we used high temperature Resonance Ultrasound Spectroscopy (RUS). We explored the temperature dependence of the full elastic moduli tensor, speed of sound, attenuation, and anisotropy of naturally occurring single crystal topaz ($Al_2SiO_4F_{1.42}(OH)_{0.58}$) [1] with a rectangular parallelepiped geometry. The RUS spectra are influenced by the geometry, density, and the full elastic moduli tensor [2]. We determined the crystal symmetry and crystallographic alignment of the crystals using X-ray diffraction. The geometry and density are well constrained from previous results on thermal expansion. The elasticity results on topaz are in good agreement with previous studies. We combine the high temperature elasticity of natural topaz with the results from the *first principles* on end member hydrous topaz and shed insight into how pressure temperature and composition, i.e., the fluorine and hydrogen content could influence elasticity of minerals in the Earth's interior, in particular in subduction zone settings. [Work supported by U.S. NSF Award Nos. EAR-1634422 and EAR-1753125.] References: [1] Tennakoon *et al*., *Sci. Rep*., 8, 1372 (2018). [2] A. Migliori and J. D. Maynard, *Rev. Sci. Instrum*.76, 121301 (2005).

10:45

5aPA10. Nonlinear resonant ultrasound spectroscopy using electromagnetic excitation. Joshua F. Gregg and Brian E. Anderson (BYU Dept. of Phys. and Astron., Brigham Young Univ., N283 ESC, Provo, UT 84602, joshygregg1@gmail.com)

Nonlinear resonant ultrasound spectroscopy (NRUS) is a method that can be used for detecting microcracks in structures. NRUS detects shifts in resonance frequencies versus excitation amplitude. Excitation of a sample is typically done with a piezoelectric transducer. Here, the application of an electromagnetic excitation is explored as an alternative for NRUS excitation. It involves gluing a coil of wire onto the end of a rod sample and placing it in a magnetic field. By controlling which part of the coil is in the strongest part of the magnetic field, the principle direction of the driven oscillations in the rod can be controlled. This method allows selective excitation of longitudinal, torsional, and bending vibrations, and the measurement of the nonlinear properties of the sample for each type of vibration is therefore possible. Both a piezoelectric transducer and electromagnetic excitation are used to measure the nonlinear elastic parameters of a Berea sandstone rod. The effects of heating of the sample and slow dynamics are explored and compared with each type of excitation. The purpose of this presentation is to illustrate the usefulness of the electromagnetic method and outline its differences from the piezoelectric method.

11:00

5aPA11. Temperature-dependent studies of high-performance foamed cements. Eric S. Davis, Hung Doan, Blake Sturtevant, and Cristian Pantea (Los Alamos National Lab., P.O. Box 1663, Los Alamos, NM 87545, esdavis@lanl.gov)

In this study, through-transmission acoustic time-of-flight experiments were used to study the variation of the mechanical properties of foamed cements when subjected to realistic field temperatures. Since temperature increases by ~25 °C/km in depth, it is important to understand the properties of foamed cements used in wellbore applications at relevant depths. By studying these foamed cements up to around 165 °C, characterization up to ~6 km in depth is achieved, which covers almost all drilling depths. In particular, it was found that foamed cements containing a higher percentage of air were less affected by temperature, and that Young's modulus and the compressional sound speed do not decrease linearly with the increasing air content, as one might expect. The sound speeds varied from 2942 m/s for 10% foamed cement, to 2500 m/s for 30% foamed cement at room temperature. Young's modulus varied from 16.0 GPa for 10% foamed cement to 9.2 GPa for 30% foamed cement at room temperature. The softening rate with heating also decreased with the increasing air content, with 10% foamed cement decreasing by 7.8% in Young's modulus with heating from room temperature to ~165 °C, while 30% foamed cement only decreased by 5.5%.

11:15

5aPA12. Acoustics-based 3-dimensional temperature gradient determination in paraffin wax. Cristian Pantea (MPA-11, Los Alamos National Lab., MS D429, Los Alamos, NM 87545, pantea@lanl.gov), John Greenhall (MPA-11, Los Alamos National Lab., Santa Fe, NM), Eric S. Davis, and Craig Chavez (MPA-11, Los Alamos National Lab., Los Alamos, NM)

There are currently no technologies to noninvasively assess explosive condition from outside its external confinement for explosive safety activities. Knowledge of the explosive condition inside an item can help to estimate the time that remains before thermal damage ignites the explosive, or how the explosive responds to various actions. Acoustic technologies based on COTS hardware and designed to determine temperature gradients have been in development for several years with no demonstrated success. Conventional acoustical sources at low frequencies tend to have a large beamspread with side lobes, resulting in significant acoustical energy losses and very poor spatial resolution. The use of a unique collimated low-frequency sound beam and beam scanning, developed recently in our lab, was investigated in paraffin wax for acoustic temperature determination. Acoustic through-transmission experiments, and knowledge of the relationship between sound speed and temperature led to spatially resolved three-dimensional temperature field inside the sample, in good agreement with those measured using thermocouples.

11:30

5aPA13. A comparative study of the dynamics of laser and acoustically generated bubbles in viscoelastic media. Jonathan R. Sukovich (Biomedical Eng., Univ. of Michigan, 1410 Traver Rd., Ann Arbor, MI 48105, jsukes@umich.edu), Chad Wilson (Mech. Eng., Univ. of Michigan, Ann Arbor, MI), Timothy L. Hall (Biomedical Eng., Univ. of Michigan, Ann Arbor, MI), Lauren Mancia, Mauro Rodriguez, Eric Johnsen (Mech. Eng., Univ. of Michigan, Ann Arbor, MI), and Zhen Xu (Biomedical Eng., Univ. of Michigan, Ann Arbor, MI)

Here, we present results from experiments comparing the first-cycle growth and collapse dynamics of acoustically and laser-nucleated single bubbles in water and agarose gels of varying stiffness. Experiments were carried out in a custom-built spherical vessel which allowed both acoustically and laser-nucleated bubbles to be generated at its center. Bubbles were nucleated in water and agarose gels with stiffnesses ranging from 1.13 kPa to 570 kPa. Acoustically nucleated bubbles were generated using pulses delivered from 1 MHz transducer elements mounted in the vessel with pulse durations of <2 acoustic cycles. Laser-nucleated bubbles were generated using a pulsed Nd:YAG laser focused to the center of the vessel through an embedded window. Bubble dynamics were measured via optical imaging. The maximum radii of generated bubbles decreased with the increasing material stiffness for bubbles nucleated by both mechanisms. The growths and collapses of the bubbles occurred symmetrically (in time) about the maximum radius in water but not in gels, where the duration of growth decreased more rapidly than collapse as gel stiffness increased. Nucleation-mechanism-dependent differences in the growth-collapse asymmetry were observed which indicated that the growth duration of the laser-nucleated bubbles was longer than the acoustically nucleated bubbles in water and high water-content gels.

11:45

5aPA14. The effect of tapered entrance in nozzle flow cavitation. Grace McDonough, Jennifer M. Moreira, Ankush Gupta, Emily Ryan, Sheryl Grace, and R. Glynn Holt (Boston Univ., 110 Cummington Mall, B-08, Boston, MA 02215, gracemcd@bu.edu)

Cavitation erosion is a common cause of damage of fuel injectors, pumps, and other hydrodynamic equipment. For fuel injectors, cavitation can also have a beneficial effect on the resultant spray angle and aerosol size distribution. Because collapsing cavitation bubbles emit pressure waves, the occurrence and extent of cavitation can be characterized using an ultrasonic transducer in the spirit of passive cavitation detection, commonly employed in biomedical acoustics. Experiments use a two-part acrylic nozzle: a contraction portion of length 1 in. (contracting from the feed tube diameter of 1.14 in. to the diameter of the cylindrical portion) and a cylindrical outlet of length 1 in. Two different outlet diameters have been considered. Water is caused to flow at increasing rates which span the inception and development of hydrodynamic cavitation. Acoustic and optical results will be presented and compared. The results indicate that introducing a tapered change in the nozzle diameter delays the onset of cavitation with respect to the mean flow rate, as does decreasing the taper angle with respect to the flow axis. [Work supported by DOE DE-EE0007332.]

FRIDAY MORNING, 17 MAY 2019 GRAND BALLROOM C, 8:00 A.M. TO 12:00 NOON

Session 5aSC

Speech Communication: Production (Poster Session)

Olga Dmitrieva, Chair
Purdue University, 640 Oval Drive, Stanley Coulter 166, West Lafayette, IN 47907

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

Contributed Papers

5aSC1. Patterns of vowel nasality in Brazilian Portuguese. Luciana Marques (English, Colorado State Univ., 359 Willard O. Eddy Hall, 1773 Campus Delivery, Fort Collins, CO 80523-1773, luciana.marques@colostate.edu) and Rebecca Scarborough (Linguist., Univ. of Colorado at Boulder, Boulder, CO)

This study aims to establish differences in patterns of acoustic nasality between nasal and nasalized vowels in Brazilian Portuguese (BP). The difference in how nasality is implemented in the acoustic signal is hypothesized to reflect the different phonological status of these two vowel categories. Acoustic nasality is the difference between the amplitude of the first formant (A1) and the amplitude of a harmonic in the low region of the vowel spectrum (P0) (Chen, 1997). The smaller the difference between these peaks, the more nasal a vowel is. A1-P0 measurements were taken at different time points from recordings of oral, nasal, and nasalized vowels in BP of five qualities. Results show that nasal and nasalized vowels were similar in all qualities. However, the way nasality is implemented over time between the vowel categories are different, with acoustic nasality in nasal vowels increasing more rapidly than in the nasalized counterparts. Although the patterns of nasality found are not consistent with the expected nasal profile difference (Cohn, 1990), the difference in acoustic nasality between nasal and nasalized vowels is consistent enough to consider it result of how the feature [nasal] is implemented in the language due to its variable phonological status in BP.

5aSC2. The prosody of corrective focus and its domain in Korean. Miran Oh and Dani Byrd (Linguist., Univ. of Southern California, 3601 Watt Way, Grace Ford Salvatori 301, Los Angeles, CA 90089, miranoh@usc.edu)

Speakers place focus on specific linguistic elements using systematic modulations to highlight new or important information. Focus effects have primarily been studied for domains larger than a segment, such as syllables or words. By eliciting focus on segment-sized units using a corrective focus task, this study examines at what granularity or scope speakers manifest focus and its acoustic consequences for consonants differing in gestural and tonal compositions. Data were obtained from 16 native Korean speakers producing corrective focus on segments having varying syllable-internal positions (i.e., onset, nucleus, versus coda focus) and varying segmental compositions (i.e., tense and lax consonants). The results indicate that the patterns of focus modulation do not differ depending the on anticipated sub-syllabic focus position but rather are exhibited through the syllable. This suggests that the domain of focus extends beyond segment-sized intervals. Moreover, focus is manifested with systematic variations as a function of the gestural compositions active during its domain. Finally, there is some support for an interaction among multiple prosodic gestures—focus gestures and accentual phrase tone gestures. Overall, evidence suggests that focus has a syllable-sized (or larger) scope of effect that is sensitive to co-active articulatory and prosodic (tonal) gestures. [Work supported by NIH.]

5aSC3. A cross-linguistic comparison on the use of acoustic cues for ambiguity resolution. Hyunah Baek (Dept. of Linguist., Stony Brook Univ., Stony Brook, NY 11790, hyunah.baek@stonybrook.edu)

In producing structurally ambiguous sentences, speakers often rely on prosodic acoustic cues (duration, pitch, and intensity) to enhance communication. This study compared speakers of two languages in their use of these cues for ambiguity resolution. Ten English and 10 Korean speakers completed a production task in their native language. Stimulus sentences included a relative clause which could modify either the first or the second noun (e.g., *the boss of the clerk who was dishonest*). The participants produced each sentence twice, being directed each time to convey one or the other of the two possible meanings. English speakers used higher pitch and greater intensity on a word when it was being modified, but their use of durational cues was less consistent. Korean speakers, in contrast, consistently used lengthening on phrase-final word

and longer pauses at the major constituent break, but their use of pitch and intensity was not consistent. These results suggest that to resolve parallel structural ambiguities, English speakers use pitch and intensity cues while Korean speakers use durational cues. I argue that this difference relates to the prosodic systems of each language, with English using pitch accents associated with words and Korean using boundary tones associated with accentual phrases.

5aSC4. Coarticulation varies by consonant identity in adult and child speech. Margaret Cychosz (Dept. of Linguist., Univ. of California, Berkeley, 1203 Dwinelle Hall #2650, Berkeley, CA 94720, mcychosz@berkeley.edu)

Consonant-vowel coarticulation varies by manner of articulation: speakers coarticulate less between segments in V[stop] sequences than V[glide]. There are different approaches to modelling consonant identity effects upon coarticulation (Iskarous *et al*., 2013). However, these effects have not been studied in non-literate populations—young children or non-literate adults. This is relevant since literacy heightens phoneme awareness, affecting coarticulation. 40 South Bolivian Quechua speakers who were not literate in the language, 30 children (aged 5–10) and 10 adults, completed a picture-prompted word elicitation task. Coarticulation was measured between [a] and the consonants /p, t, k, k^h, q^h, ch, s, m, w/ in VC and CV syllables. Because the child speech apparatus poses problems for typical spectral analysis, we quantify coarticulation as the Euclidean distance between Mel frequency cepstral coefficient vectors averaged over adjacent phones (Gerosa *et al*., 2006). Mixed effects models predicting the Euclidean distance between adjacent phones show that all age groups are sensitive to changes in consonant manner. Adults and children restrained coarticulation more between sequences containing obstruents than glides or liquids. These results suggest that literacy and heightened phoneme awareness are not required for consonant identity to affect coarticulation.

5aSC5. The acoustic effects of emphatic and pharyngeal consonants on adjacent vowels. Laura R. Faircloth (Dept. of Linguist., Univ. of Texas at Austin, 305 E 23rd St., STOP B5100 RLP 4.304, Austin, TX 78712, lrfaircloth@utexas.edu)

Emphatic consonants in Arabic are coronal obstruents with a debated secondary articulation, contrasting with plain coronals and affecting adjacent vowels (Watson, 2007). The secondary articulation has been claimed to be pharyngeal, so pharyngeals may affect vowels similarly. Eight speakers of Palestinian Arabic recorded words with /a:/, /i:/, or /u:/ following plain /s/ , empathic /sˤ/, or pharyngeal /ħ/. The effects of plain and emphatic consonants on /a:/ have been studied, but other vowels may be affected differently. The CoG of /sˤ/ was lower than /s/, differing from previous studies (Card, 1983). F1 and F2 measurements from the onset, midpoint, and offset of the vowel showed the extent of emphatic effects. F2 in /a:/ and /i:/ and F1 in /a:/ and /u:/ adjacent to /sˤ/ were lower than adjacent to /s/ or /ħ/. Both suggest a backed and raised tongue in emphatics. F1 was only higher adjacent to /ħ/ at the onset, while emphatics affected the entire time course. Pharyngeal /ħ/ caused typical coarticulation, while the longer effects of emphatic /sˤ/ suggest a phonological process. The differences between emphatic and pharyngeal consonants also suggest that emphatic consonants in this dialect are produced with uvular constriction, not pharyngeal as has been claimed.

5aSC6. Trade-offs between labial and lingual activity in the Suzhou Chinese labial fricative vowels. Matthew Faytak, Jennifer Kuo, and Shunjie Wang (Dept. of Linguist., Univ. of California, Los Angeles, UCLA, 3125 Campbell Hall Box 951543, Los Angeles, CA 90095, faytak@ucla.edu)

We examine trading relations between lingual and labial activity for three back vowels with different labial constrictions in Suzhou Chinese. Specifically, we compare the labial "fricative vowels" [ɯ͡β] and [ɯ͡ʋ], which exhibit a compressed lip opening and a labiodental constriction, respectively, with rounded [u]. Linear mixed-effects modeling of indices of tongue contour shape extracted from ultrasound video demonstrates that the degree of tongue dorsum raising differs systematically from vowel to vowel: [ɯ͡β] and [ɯ͡ʋ], which have more labial constriction than [u], exhibit reduced back raising activity compared to [u]. We additionally report on correlations between lingual activity and labial activity based on the frontal lip shape and lip aperture data collected from a time-aligned video channel.

5aSC7. Structured variation in Suzhou Chinese fricative consonants and vowels. Matthew Faytak (Dept. of Linguist., Univ. of California, Los Angeles, UCLA, 3125 Campbell Hall Box 951543, Los Angeles, CA 90095, faytak@ucla.edu)

Uniform phonetic implementation of phonological primitives has been suggested to be a low-level constraint on speech production. Suzhou Chinese offers an example of how this constraint may shape the development of systems of phonological contrast: a pair of recently innovated "fricative vowels," rounded and unrounded, have come to be produced with the addition of noticeable fricative noise. This noise is spectrally similar to that of a fricative consonant, most frequently alveolopalatal /ɕ/ but occasionally /s/, suggesting that speakers have begun to refer to shared acoustic targets for these phonotactically dissimilar sounds. In order to assess the degree of acoustic similarity among these segments, we compare the fricative noise in the unrounded and rounded fricative vowels of 43 speakers of Suzhou Chinese with the fricative noise of each speaker's onset fricative consonants /ɕ/ and /s/. Spectral parameters analyzed are chosen to reflect constriction anteriority in strident fricatives. Correlations in these parameters as implemented across consonantal onsets such as /ɕ/ and /s/, and the unrounded fricative vowel and the rounded fricatie vowel are examined.

5aSC8. A kinematic investigation of coarticulation resistance in Modern Greek. Evdoxia Doli (Behavioral and Brain Sci., Callier Ctr. for Commun. Disord., The Univ. of Texas at Dallas, 1966 Inwood Rd., Dallas, TX 75207, exd160330@utdallas.edu) and William F. Katz (Behavioral and Brain Sci., The Univ. of Texas at Dallas, TX)

In order to examine the coarticulation resistance hypothesis (CRH) this study investigated patterns of CV and C1C2V overlap in consonant clusters and matching singletons in Greek, including five places of articulation in C2V position (bilabials, labiodentals, interdentals, alveolars, and velars). Stimuli were recorded from three talkers producing eight repetitions of each item, embedded in a carrier phrase. Kinematic and acoustic data were acquired with an electromagnetic articulography (EMA) system. Temporal measures were obtained by determining timing lags for both singletons and clusters, while spatial measures were found by calculating the Euclidean Distance (ED) of the tongue back sensor from the C2V velocity peak to that of the following vowel, for both singletons and clusters. Logarithmic ED ratios for each stimulus triplet (e.g., "ba"-"la"-"bla") were then computed to test whether C2V allows C1V to exert coarticulatory influence on the vowel. Preliminary findings from both the temporal and spatial analyses suggest pronounced differences in complex versus simple syllable organization as a function of C2V place of articulation. The extent to which these results support the CRH will be further discussed.

5aSC9. Acoustical emphasis not possible: The case of emphatic morphemes in Lakota. Brooke L. Kidner (Linguist., Univ. of Southern California, 620 McCarthy Way, #273, Los Angeles, CA 90089, bkidner@usc.edu)

In languages like English, emphasis can be expressed acoustically by an increase in pitch or amplitude. These types of pitch excursions and increase in amplitude are often how metrical stress is marked in languages. This type of representation of metrical stress is true for Lakota. While this type of acoustic representation of stress is not uncommon, it does present a unique problem for Lakota speakers when it comes to encoding emphasis acoustically in their speech. Lakota (a member of the Dakota family of languages with less than 9000 speakers), has a very rigid set of rules for where stress can be applied in languages, often having several minimal pairs that differ only in which syllable receives primary stress. As such, they are unable to utilize these common acoustic markers for emphasis in their speech. Field research conducted on the Pine Ridge Reservation (2018, 2016) has resulted in the discovery that Lakota possesses two emphatic morphemes: [kʃto] for female speakers and [jelo] for males, which speakers utilize to encode emphasis into their speech.

5aSC10. The lingual topography of American English laterals in onsets and codas. Kenneth de Jong, Kelly Berkson (Dept. of Linguist., Linguist, Indiana Univ., 1021 E. Third St., Mem 322E, Bloomington, IN 47405, kberkson@indiana.edu), Steven M. Lulich (Speech and Hearing Sci., Indiana Univ., Bloomington, IN), Samantha Myers, and Amanda Bohnert (Linguist., Indiana Univ., Bloomington, IN)

This paper reports on a three-dimensional/four-dimensional ultrasound investigation of American English laterals. Traditional descriptions of English distinguish between pre-vocalic (onset) laterals ('light-l'), said to involve a coronal gesture creating an alveolar occlusion on the center line with lateral venting, and post-vocalic (coda) laterals ('dark-l'), said to involve both the coronal gesture and an additional dorsal constriction gesture. Recent work suggests that this view of laterals may be overly simple: e.g., onset laterals in American English may also have a dorsal gesture [Rhodes *et al*., *JASA*137(4), 2268–2269 (2015)]. Previous work also noted a persistent tongue configuration involving deep cupping of the midline in the palatal region yielding a raised tongue tip and dorsum around the cupped region. This configuration appears in both onsets and codas, even for a speaker who exhibited no coronal contact [Berkson *et al*., *ICASSP* (2017), pp. 5080–5084]. This study presents configurations for 20 college-aged native speakers of English (10 female) who show individual differences in (i) the presence of palatal grooving and (ii) consistency between onset and coda configurations. We contend that the onset versus coda lateral distinction cannot be reduced to a single description in terms of lingual configuration.

5aSC11. Acoustic and articulatory investigation of the Mauritian vowel inventory. Samantha Myers (Lingustics, Indiana Univ., Bloomington, IN), Fabiola Henri (Linguist., Univ. of Kentucky, Lexington, KY), and Kelly Berkson (Dept. of Linguist., Indiana Univ., 1021 E. Third St., Mem 322E, Bloomington, IN 47405, kberkson@indiana.edu)

While there have been a decent amount of morphosyntactic and sociolinguistic studies on Mauritian, a "French-based" creole spoken by most of the population of Mauritius (e.g., Baker, 1972; Alleesaib, 2012; Henri, 2010; Miller, 2015; Syea, 2013), phonetic or phonological description on the language hardly exists. Pudaruth (1993) proposes a phoneme inventory consisting of 19 consonants and 8 vowels, intuitively noting that rhotics preceding vowels are weakened, almost unpronounced. In the present work, we empirically investigate the vowel inventory of Mauritian using acoustic and articulatory data. In addition to presenting basic acoustic measures (e.g., vowel spaces), we note the presence of a rhotic, and report acoustic measures which suggest strong variation between the orthographic "a" that precedes "r" and that which precedes all other written consonants. Ultrasound imaging confirms that the pre-rhotic "a" differs from other "a"s articulatorily.

5aSC12. Quantity, quality, both or neither? Vowel contrasts in Hakha Chin monophthongs. Rebecca Haley, Samson A. Lotven, James Wamsley, and Kelly Berkson (Dept. of Linguist., Indiana Univ., 1021 E. Third St., Mem 322E, Bloomington, IN 47405, kberkson@indiana.edu)

Hakha Chin—a Tibeto-Burman language spoken in Chin State in western Myanmar—is reported to have phonemic length distinctions in its monophthongs (Melnik, 1997; Peterson, 2003; Maddieson, 2004) (e.g., [ii] vs. [i], [aa] vs. [a]). These pairs are also sometimes represented with tense/lax vowels (e.g., [i] vs. [ɪ], [a] vs. [ə]) (Peterson, 2017). Indeed, the results of a perception study conducted by Mortenson and Van Bik (2002) found variable response patterns in different dialect groups. Listeners from Hakha, the city after which the language is named, relied heavily on spectral cues related to quality to distinguish between long and short vowels, while listeners from the town of Thanthlang relied mainly on durational cues to perform the same task. In the current study, we present the first instrumental acoustic analysis of Hakha Chin vowel quality in order to aid in elucidating the nature of the contrast. Data from three college-aged native speakers (two male) suggest that neither duration nor quality play key roles in distinguishing between the so-called long and short vowels of Hakha Chin. Rather, as originally suggested by Maddieson (2004), the length associated with long vowels is mainly realized through lengthening of sonorant codas.

5aSC13. Pitch accent and the three-way laryngeal contrast in North Kyungsang Korean. Young Hwang, Samson A. Lotven, and Kelly Berkson (Dept. of Linguist., Indiana Univ., 1021 E. Third St., Mem 322E, Bloomington, IN 47405, kberkson@indiana.edu)

Previous description of Korean's three-way voiceless stop contrast notes differentiation in both voice onset time (VOT) and fundamental frequency (f0) on following vowels (Cho *et al*., 2002; Kang and Han, 2013; Kang, 2014). In a sound-change in-progress, however, VOT for lenis and aspirated stops has merged. The two are now differentiated primarily through f0 differences (Kang and Guion, 2008; Lee *et al*., 2013; Silva, 2006). North and South Kyungsang (NK and SK) are pitch accent dialects. SK has not undergone the change (Lee and Jongman, 2012): VOT is still a primary cue, potentially because f0 is already used for the pitch accent system (Lee *et al*., 2013). In NK, meanwhile, VOT for lenis and aspirated stops overlaps more for female than for male speakers, suggesting a possible change-in-progress (Holliday and Kong, 2011). As questions about the robustness of this change remain, we report data from 23 native NK speakers (6 older and 6 younger males; 5 older and 6 younger females). VOT and f0 findings suggest that the new pattern is incipient in NK: Older male talkers show the old pattern, younger female talkers the new pattern, and older female and younger male talkers fall between the two extremes.

5aSC14. A phonetic study of Swahili voiced stops. Jeremy Coburn and Nils Hjortnaes (Linguist., Indiana Univ., Ballantine Hall 821, 1020 E. Kirkwood Ave., Bloomington, IN 47405, nhjortn@iu.edu)

Despite a rich history of general linguistic research, discrepancy exists within the literature on the phonetic description of voiced stops in Swahili. Polome (1967) reports the voiced stops are phonemically implosive, with plosive allophones in some environments, but which may be strictly egressive for some speakers. Additionally, he states that other speakers have implosives for all stops (i.e., [ɓ], [ɗ], [ɟ]) except the voiced velar plosive [g]. Contemporary descriptions classify all the voiced stops as pulmonic voiced plosives (Mohamed, 2001). This study is an acoustical examination of voiced stops of Swahili speakers from various regions of Tanzania and Kenya to determine the presence of implosives in Swahili and its dialects. The parameters under observation include: (1) voicing onset time (VOT), (2) voicing terminating time (VTT), (3) amplitude, and (4) closure duration as described in several works (Nihalani, 1986; Clements and Osu, 2002; Chávez-Péon, 2005; especially, Cun, 2009). This study discusses preliminary findings on the analysis of five speakers' productions. Four speakers were found to have implosives in all cases except prenasalized voiced stops. One speaker produced plosives in all instances. The results suggest that variation does occur and further research is needed to establish a better description of the language.

5aSC15. Effect of simultaneous lip-tube and auditory feedback perturbations. Lambert Beaudry (Linguist., Universite du PQ a Montreal, Montreal, QC, Canada), Pascal Perrier (GIPSA-Lab, Saint Martin d'Hères, France), and Lucie Menard (Linguist., Universite du PQ a Montreal, CP 8888, succ. Centre-Ville, Montreal, QC H3C 3P8, Canada, menard.lucie@uqam.ca)

In a series of previous experiments, it has been shown that when required to produce the back rounded vowel /u/ with a lip-tube perturbation that prevents lip rounding, speakers reached the auditory goal associated with /u/ by altering their tongue position. In the present study, the importance of sensory feedback was further investigated by combining lip-tube and auditory feedback perturbations. Fifteen adult francophone speakers produced 5 blocks of ten /u/ tokens under various conditions (following and preceding a baseline condition). First, tokens were produced when the speakers had a lip-tube in place (predicted to increase F1 and F2) as well as a real-time auditory feedback perturbation (designed to cancel the acoustic effects of the lip-tube, that is, to decrease F2 and F1). Next, only the lip-tube perturbation was applied, with and without white noise. Formant values for each condition were extracted at the vowel midpoint. Although most speakers produced a larger compensatory response with the lip-tube alone condition than with the combined lip-tube and auditory perturbation condition, all speakers produced altered formants in the latter condition. This suggests that speakers try to reduce auditory and somatosensory feedback

errors during speech production, with a speaker-specific weighting of each sensory modality.

5aSC16. Effects of focus and tone on vowel space in Chongming Chinese. Yike Yang, Bei Li, and Si Chen (Dept. of Chinese and Bilingual Studies, The Hong Kong Polytechnic Univ., AG511, Kowloon, Hong Kong, yike.yang@connect.polyu.hk)

The formant frequencies of vowels are prone to change according to contexts, but the effects of focus on vowel space are rarely studied. This study attempts to investigate how focus and tone may influence the vowel space in Chongming Chinese with a production experiment. Chongming Chinese is a Chinese dialect with a complex tonal system. Twelve syllables with the vowel /æ/ were chosen and the syllables spread over eight lexical tones (two level tones, four contour tones, and two checked tones). The target syllables were embedded in carrier sentences with different preceding and following syllables. Four focus conditions were manipulated: broad focus, initial focus, medial focus, and final focus. During the experiment, twelve participants were elicited with precursor questions to produce sentences with different focus locations. The frequencies of the first two formants (F1 and F2) were extracted over the middle 50 ms of the vowel interval for each target syllable. Formant tracks were calculated with the Burg algorithm in Praat. F1 and F2 values under each focus condition and tone will be compared. It is hypothesized that F1 and F2 will be increased under focus because focus might make the vowels more open and front.

5aSC17. Tahrir patterns in a professional Iranian classical singer. Mahdi Tahamtan and Ronald Scherer (Commun. Sci. and Disord., Bowling Green State Univ., Bowling Green, OH 43403, mahdit@bgsu.edu)

"Iranian classical singing" ("avaz" in Persian) contains the ornament called a tahrir. It typically is a sequence of tekyeh fundamental frequency gestures that quickly increase and then decrease. The primary aim was to determine and describe the tahrir patterns produced by a professional avaz singer. An unaccompanied recording was made of a professional avaz singer singing the popular song "Morghe Sahar" ("Dawn Bird"). Consistent patterns of tahrir productions were determined after repeated listening. Four primary tahrir patterns were identified, based on (1) the number of tekyehs within the tahrir, (2) fundamental frequency extent from the baseline to the tekyeh peaks, and (3) inter-tekyeh interval durations. Pattern 1 consists of one tekyeh and is called a "zinat." Pattern 2 is a multiple tekyeh gesture with relatively long inter-tekyeh intervals. Pattern 3 is a multiple tekyeh gesture with relatively short inter-tekyeh intervals. Pattern 4 is a vibrato-like pattern with multiple tekyehs with short inter-tekyeh intervals like Pattern 3 but with relatively short frequency extents. The results are pertinent to voice scientists interested in the mechanics of phonatory production, to singing teachers and artists interested in pedagogy based on acoustic and perceptual information, and to ethnomusicologists interested in cultural musical performance and production.

5aSC18. Nasal consonants block /o/ fronting in white and Lumbee speakers from Robeson County, North Carolina. Marie Bissell (Linguist., North Carolina State Univ., 2211 Hillsborough St., Tompkins Hall, Box 8105, Raleigh, NC 27607, marie.bissell@gmail.com)

This study examines /o/ fronting in white and Lumbee speakers in a triethnic contact situation in Robeson County, North Carolina. Previously, Thomas (1989) observed that following nasal consonants may be blocking /o/ fronting in Wilmington, North Carolina. The present study examines this hypothesis in more depth in nearby Robeson County. Nine speakers were selected from the Sociolinguistic Archive and Analysis Project (Kendall, 2010). Nucleus and glide measurements were taken for each speaker's /o/ tokens, pre-lateral /o/ tokens, and pre-nasal /o/ tokens. Values were then Lobanov-normalized. Acoustic analysis of individuals speakers' vowel spaces suggests that when /o/ fronts, pre-nasal /o/ remains back along with pre-lateral /o/. While white speakers' pre-nasal /o/ patterns closely with their pre-lateral /o/, Lumbee speakers' pre-nasal /o/ tends to glide in a different direction in what could be considered a three-way allophonic split in the /o/ vowel class. The results of this study indicate that both following lateral consonants and following nasal consonants block /o/ fronting, though the phonological mechanism underlying pre-nasal /o/ backing is in need of further investigation.

5aSC19. Coarticulatory resistance in Assamese stops. Indranil Dutta (Dept. of Computational Linguist., The EFL Univ., Hyderabad, Telangana, India), Pamir Gogoi, and Ratree Wayland (Dept. of Linguist., Univ. of Florida, Gainesville, FL 32611, pgogoi@ufl.edu)

The nature and extent of coarticulation and coarticulatory resistance of speech segments have been found to be dependent on the size, shape, and density of contrasts, in addition to neighborhood densities of segment sequences. While high density of contrasts leads to high coarticulatory resistance, low density of contrasts leads to low coarticulatory resistance. Assamese, an Indo-Aryan (IA) language, unlike the other IA languages which exhibit a two-way coronal place contrast, contains only an alveolar stop. Due to the relative low density of the alveolar, we hypothesize that the Assamese alveolar stops will exhibit low coarticulatory resistance compared to the velar counterpart. We use locus equations to analyze the coarticulatory effects. First order locus equations were used in a $[_{aCV\_}]$ context, where C is a labial, alveolar, or velar stop, while the following V is one of the corner vowels /a,i,u/. Unlike the hypothesis, the least amount of coarticulatory resistance is shown by the velars and the alveolars show greater resistance compared to the velars and the labials. This poses an interesting question because it has been stated that mostly the slopes are seen to be order of labial, then velar and then alveolar. The possible explanations are discussed.

5aSC20. Analyzing rhythmic convergence between two Swiss German dialects. Elisa Pellegrino (URPP Lang. and Space, Freiestrasse 16, Zurich 8032, Switzerland, elisa.pellegrino@uzh.ch) and Volker Dellwo (Dept of Computational Linguist., Zurich, Switzerland)

With respect to existing evidence of rhythmic adjustments in response to the interlocutor's idyosincratic characteristics, in the present study, we test whether interlocutors are likely to mutually adapt their rhythmic characteristics over the course of a conversation or after increased exposure to a dialogue partner. To study rhythmic accommodation, we used a corpus of read speech recorded by 18 speakers of two Swiss German dialects—Grison and Zurich German—before and after performing diapix tasks. The two dialects present crucial differences in the durational characteristics of intervocalic sonorants, vowel in open syllable and vowel in final position, thus creating different rhythm in these two dialects. To determine whether Grison and Zurich German speakers produce the rhythmic contrasts more similarly after the diapix tasks, we measured the Euclidean distance within a pair (*ddpair*) and within an individual (*ddspeak*) in three ratio measures devised to capture the durational differences between the two dialects. Preliminary results on *ddpair* have shown that certain durational contrasts are produced more similarly by certain pairs but more differently by other ones. Ratio measure related to the timing properties of vowels in final position does not change drastically before and after the interaction.

5aSC21. Effect of stress, harmonic status, and lexical status on Hungarian vowel-to-vowel coarticulation. Jenna Conklin and Olga Dmitrieva (Linguist., Purdue Univ., 610 Purdue Mall, West Lafayette, IN 47907, jconkli@purdue.edu)

The present study examines vowel-to-vowel coarticulation in Hungarian with particular emphasis on the effects of word stress and lexical status (real words versus nonce words) on the direction and degree of vowel coarticulation. Previous investigations indicate that lexical stress exerts a powerful influence on vowel coarticulation. Specifically, stressed vowels are thought to resist coarticulation (see, e.g., Beddor *et al*., 2002; Majors, 2006). It is not clear, however, whether this effect is universal across languages, nor if it can be suppressed by the presence of more influential factors. In addition, it is not known whether vowel-to-vowel coarticulation always affects real and nonce words in a similar fashion, though some previous research indicates that speakers differ in their coarticulatory handling of nonce words (Scarborough, 2012). Finally, previous research suggests that the presence of vowel harmony in a language may place restrictions on the direction of vowel-to-vowel coarticulation (Beddor and Yavuz, 1995). Hungarian has a vowel harmony system that includes several neutral vowels, which do not participate in harmony. This study reports the results of an acoustic analysis

of coarticulation in stressed and unstressed vowels (both neutral and harmonizing) in real and nonce words produced by native speakers of Hungarian.

5aSC22. Variation in voice quality within speakers. Yoonjeong Lee and Jody E. Kreiman (Head and Neck Surgery, Univ. of California, Los Angeles, 31-19 Rehabilitation Ctr., 1000 Veteran Ave., Los Angeles, CA 90095, yoonjeonglee@ucla.edu)

Little is known about the nature or extent of everyday variability in voice quality within a speaker or how this differs across speakers. Using a suite of measures that map between acoustics and perception of voice quality, this study elucidates which acoustic variables within speakers' individual voice spaces best characterize speakers. Based on studies of faces and cognitive models of speaker recognition, we hypothesized that a few measures would be important across speakers, but that much intra-speaker variability would be idiosyncratic. By using principal component analysis, we tested this hypothesis against a set of multiple sentence productions from 100 native speakers of English (fifty females and fifty males), recorded over three days. Acoustic variables measured every 5 ms on vowels and approximants corresponded to F0, vowel quality, spectral noise, source spectral shape, and variability. Across speakers the balance between higher harmonic amplitudes and inharmonic energy in the voice accounted for the most variance (females = 20%/males = 22%). Vowel quality and its variability accounted for an additional 12%/12% of variance. Remaining variance appeared largely idiosyncratic, suggesting that the speaker-specific voice space is different for different people. Notably, F0 did not emerge from these analyses. Implications for voice recognition are discussed. [Work supported by NIH/NSF.]

5aSC23. Vowel coarticulation in the Buckeye corpus. Sean A. Fulop (Linguist., California State Univ. Fresno, 5245 N Backer Ave., PB92, Fresno, CA 93740-8001, sfulop@csufresno.edu) and Hannah Scott (Elec. Eng. and Comput. Sci., Oregon State Univ., Corvallis, OR)

Theories of vowel perception, production, and acquisition have moved on from the early simple assumption of a single target for each vowel in auditory space, and yet modern variations continue to employ this notion in more sophisticated garb. The vowel prototype is lately conceived as the result of an auditory processing function incorporating information about both vowel dynamics and flanking sounds. Vowel sounds most often are flanked by consonants which are coarticulated with the vowel. It is commonly presumed that listeners apply an unknown auditory transformation to undo the coarticulatory effects when processing speech cognitively. This presumption requires coarticulation to be systematically predictable from neighboring consonants, which some studies have not found to be the case. The present study examines the vowel formants of 35 speakers from the Buckeye corpus of American English. It is found that consonant-vowel coarticulation effects are not sufficiently systematic across speakers to be predictable from the consonants. Moreover, since the coarticulation effects are so large and ubiquitous, there are no "ideal" vowels to be found in the data. There appears to be no way to transform such acoustic data by relying on the consonants that could yield a set of ideal vowel prototypes.

5aSC24. Voice actors imitating child speech: A study using 3D ultrasound. Colette Feehan and Steven M. Lulich (Linguist., Indiana Univ., Bloomington, 107 s Indiana Ave., Bloomington, IN 47404, cmfeehan@indiana.edu)

Voice actors are an interesting population for linguistic study because their profession requires them to perform complex vocal tract manipulations in order to portray specific social identities and convey socially indexed linguistic information. Previous investigations have looked at how voice actors manipulate laryngeal setting and voice quality to portray specific character types in animation (Teshigawara and Murano, 2004; Starr, 2015), but investigations of articulatory manipulations employed by voice actors are rare. This study uses three-dimensional ultrasound, formant, and F0 analyses to compare the strategies that one amateur and one professional voice actor use in order to imitate child speech. Preliminary analysis shows that the amateur actor relies on manipulation of articulatory setting by implementing hyoid bone raising, gesture fronting, and tongue grooving in order to sound like a child. The professional actor relies more on manipulation of laryngeal structures and prosody. Despite these differences in approach, the two actors still achieve similar child-like percepts. This study will describe the differences in strategy implemented by each actor as well as the within-subject variation across each actor's adult and imitated child voices.

5aSC25. Tracking sources of formant frequency variation in data from a time-controlled speech production task. Stefon M. Flego (Linguist., Indiana Univ., Bloomington, 720 S College Mall Rd. Apt. N5, Bloomington, IN 47401, sflego@indiana.edu)

Vowel formant structure is particularly sensitive to influence from neighboring segments in connected speech. Statistical models can successfully account for acoustic variability from multiple simultaneous sources of variance, such as anticipatory effects of following consonants and vowels (see, for example, Cole *et al*., 2010). Statistical approaches have also been developed to predict context segments from static measures of spectral variation like mean or midpoint formant frequencies. This study examines shifts in the relative strength of these sources of variance over the course of the target vowel, and compares previous approaches to predicting the identity of upcoming segments with a novel approach which is cumulatively informed by formant frequency variation as it unfolds temporally. Data are from 32 participants who produced target-context word sequences (permutations of …V_1C#hV_2…, where V_1 = [ɛ], C = [θ f], and V_2 = [i ɛ æ ɑ u], e.g., "deaf-heating") within a carrier sentence. Timing and prosody were strictly controlled by entraining the syllable rate to a metronome. Context word onset was always [h], which has no intrinsic supralaryngeal articulation and only begins foot-initial syllables in English. This ensured a consistent prosodic boundary between target and context words and prevented resyllabification of C across words.

5aSC26. The acoustics of feeling: Emotional prosody in the *StoryCorps* corpus. Rachel M. Olsen (Linguist, Univ. of Georgia, 142 Gilbert Hall, Athens, GA 30602-6205, rmm75992@uga.edu)

Effective communication depends not only on lexical content but also on how language is produced and perceived. Prosodic elements such as intensity, pitch accent (i.e., the pattern of low and high tones used in a stressed word), and intonation, have been suggested to aid in conveying emotional affect (e.g., happiness) in acted speech. For example, the word "yes" produced with a falling tone, high intensity, and large pitch range may indicate a high-arousal emotion like anger, whereas the same word produced with a flatter intonation, and lower intensity may indicate a low-arousal emotion like gloominess. Understanding the emotion with which words are produced facilitates appropriate communication because it tells the interlocutor how to best respond. Although this is intuitively true, the role of prosody in conveying emotional meaning is understudied, particularly in natural speech. This project thus utilizes *StoryCorps,* an extensive corpus of naturalistic interviews (publicly available at www.storycorps.org), to acoustically analyze pitch-accent usage in speech conveying different emotional affects. Portions of the *StoryCorps* interviews that convey overt emotional effect are selected and transcribed, and f0 trajectory, pitch range, duration, and intensity are tracked across stressed vowels to explore whether there are distinctive pitch-accent patterns used to convey different emotions.

5aSC27. Phonetic convergence and divergence in the American Midwest. Cynthia G. Clopper and Ellen Dossey (Ohio State Univ., 1712 Neil Ave., Oxley Hall 100, Columbus, OH 43210, clopper.1@osu.edu)

The magnitude of phonetic convergence in word shadowing is affected by phonetic factors, including the shadowers' phonetic distance from the model talker, and social factors, including the perceived prestige of the model talker's variety. The current study explored the effects of these factors on phonetic convergence to the Northern dialect of American English by shadowers from the Midwestern United States. The shadowers read a set of target words to provide their baseline productions and then repeated the same target words after a native speaker of the Northern dialect. The target words contained stressed vowels that are phonetically shifted in the Northern dialect relative to other American English varieties. Phonetic convergence in word duration and vowel formant frequencies was observed for some vowel categories but not others. This phonetic selectivity was not driven by the acoustic distance between the shadowers' baseline productions

and the model talker's productions. Phonetic convergence in word duration and vowel formant frequencies also varied depending on whether or not the shadowers were told where the model talker was from, leading to divergence for some dialect-specific features in the shadowing task. These findings provide additional evidence for the roles of phonetic and social factors in phonetic convergence.

5aSC28. Sociolinguistic differences in production of pre-nasal /o/: Evidence from Southeastern Ohio. Peter A. Andrews (English, North Carolina State Univ., Tompkins Hall, Raleigh, NC 27606, paandrew@ncsu.edu)

This study investigates the production of /o/ among 14 young adults (ages 18–24) in Athens, Ohio. This vowel is phonetically atypical because it is subject to lexical and phonological conditioning among non-native Athenians living in Athens. To better understand the phonological effects of a following nasal on /o/, the speech of 14 native southeast Ohioans was analyzed acoustically. The data come from sociolinguistic interviews selected from the Southeast Ohio Language Project corpus (Lee *et al*., 2018). The first two formants of each token of /o/ were extracted (n = 1468), normalized (Lobanov, 1971), and plotted. A mixed effects model was applied to the normalized F2 data to uncover interactions between location (Athens versus non-Athens) and vowel class. Results of the analysis suggest that non-Athenians have a significantly higher F2 value for /o/ than Athenians, and further that non-Athenians distinguish between two /oN/ allophones depending on the lexical item, a distinction that Athenians seem to lack. Furthermore, this fronting effect is more pronounced in words that have a preceding post-alveolar or labiovelar consonant, both of which are likely to result in a higher F2 of the vowel. These findings are an important contribution toward a more thorough understanding of pre-nasal phonological conditioning.

5aSC29. Acoustic, non-invasive measurement of velopharyngeal aperture using a high frequency tone. Kevin B. McGowan (Linguist., Univ. of Kentucky, 1415 Patterson Office Tower, Lexington, KY 40506, kbmcgowan@uky.edu), Michael T. Johnson (Elec. and Comput. Eng., Univ. of Kentucky, Lexington, KY), Aleah D. Combs (Linguist., Univ. of Kentucky, Lexington, KY), and Mohammad Soleymanpour (Elec. and Comput. Eng., Univ. of Kentucky, Lexington, KY)

Many researchers need access to the real time articulatory state of the velopharyngeal port to investigate the timing and extent of nasal gestures alongside the acoustic consequences of those gestures. While numerous methods exist for the investigation of nasalization (e.g., airflow, velotrace, and nasometer), these methods tend to be invasive, expensive, or to muffle the acoustic speech signal in pursuit of nasal articulatory data. We describe an inexpensive method and procedure for the investigation of nasal gestures using low frequency ultrasound. This system injects a 20 kHz tracer tone into a nostril using inexpensive components and/or three-dimensional printed parts. This signal can then be collected along with the speech signal using microphones typical in speech research. We will compare the results of this system to those of a state of the art airflow collection system and compare cross-participant reliability of both methods.

5aSC30. A non-primary cue in spontaneous imitation of English voiceless stops. Harim Kwon and Yuting Guo (English, George Mason Univ., 4400 University Dr., 3E4, Fairfax, VA 22030, hkwon20@gmu.edu)

When speaker-listeners are exposed to an exaggerated primary cue, they spontaneously imitate the enhanced cue; e.g., English speakers imitate extended VOTs of voiceless stops (e.g., Nielsen, 2011). Kwon (2015) claims that speaker-listeners enhance the primary cue for the relevant contrast when exposed to an enhanced non-primary cue, showing that Seoul Korean speakers imitated aspirated stops with an enhanced non-primary cue (stop VOT) by exaggerating the primary cue for phonological aspiration in the language (post-stop f0). However, VOT in Seoul Korean, despite being a non-primary cue, may enjoy a special status, since it is required to maintain the full three-way laryngeal contrast in the language. This study examines how the non-primary cue enhancement is imitated when the cue is not necessary for the relevant contrast. Native speakers of American English heard and spontaneously imitated English /t/ with either extended VOT (the primary cue for English voicing contrast) or raised post-/t/ f0 (a non-primary cue). Participants' own productions of English /t/ and /d/ before and after the exposure were compared. Preliminary findings suggest that the participants produced /t/ with longer VOT and higher post-stop f0 after hearing the stimuli with either manipulation but to a lesser degree after the f0-raised stimuli than the VOT-extended stimuli. The role of a non-primary cue in spontaneous imitation will be discussed.

5aSC31. Respiratory and electroglottographic measures of normal and loud speech across vowels. Laura L. Koenig (Haskins Labs. and Adelphi Univ., 300 George St., New Haven, CT 06511, koenig@haskins.yale.edu) and Susanne Fuchs (Leibniz-Ctr. General Linguist., Berlin, Germany)

Louder speech is primarily associated with greater respiratory system driving pressures, but several studies have indicated that speakers may also adjust their laryngeal settings in louder speech. In combination, these observations suggest the possibility of a tradeoff between respiratory and laryngeal mechanisms for increasing loudness, but little past work has obtained both respiratory and laryngeal measures in multiple speakers to assess the range of individual strategies. In this study, we assess measures of voice quality obtained from electroglottographic [EGG] signals in multiple female speakers. Respiratory kinematics, obtained by inductance plethysmography, were recorded simultaneously. Louder speech was obtained naturalistically, by changing speaker-interlocutor distance. Previous analyses of the respiratory data indicate that speakers differ considerably in how much they vary their respiratory kinematics when producing loud speech. We hypothesize that speakers who show less variation in their respiratory behavior will show more extreme changes in the EGG signals between normal and loud speech. We will also evaluate whether EGG differences between normal and loud speech vary as a function of vowel quality, in light of past work showing systematic differences in voice quality measures across vowels.

5aSC32. Applying refined automatic formant measurement to determination of the orientations of vowel distributions. Jeff Mielke, Erik R. Thomas (English, North Carolina State Univ., Box 8105, Raleigh, NC 27695, erthomas@ncsu.edu), Josef Fruehwald (Linguist. and English Lang., Univ. of Edinburgh, Edinburgh, United Kingdom), Jane Stuart-Smith (English Lang. and Linguist., Univ. of Glasgow, Glasgow, Scotland, United Kingdom), Morgan Sonderegger (Lingusitics, McGill Univ., Montreal, QC, Canada), Robin M. Dodsworth (English, North Carolina State Univ., Raleigh, NC), and Michael E McAuliffe (Lingusitics, McGill Univ., Montreal, QC, Canada)

In order to remedy recurrent problems with false formant readings obtained with an automatic formant measurement routine, prototype-based automatic measurements were compared with manual formant measurements of the same uttered vowels. Two refinements that avoided false formants, one involving the option to skip measured formant racks and the other involving an expectation that successive formants would show successively lower amplitudes, were developed. This method was then applied to seven corpora representing diverse English dialects, with satisfactory results. The measurements of each vowel thus obtained were then subjected to principle component analysis to determine the orientation of the tokens in F_1/F_2 space. Most vowels exhibited distributions that apparently reflect degree of jaw opening. However, /u/ in North American varieties (with pre-/l/ and post-/j/ tokens excluded) showed mostly horizontal orientations, even when post-coronal and non-post-coronal tokens were considered separately. This pattern contrasted sharply with the vertical orientations of mid back vowels. /u/ was also the only vowel whose orientations coincided consistently with ongoing changes in the communities. We hypothesize that the factors responsible for the horizontal orientations of /u/ also lie behind its cross-linguistic tendency to shift frontward.

5aSC33. A comparison of prosodic patterns in English bi-morphemic lexical and function words. Irina A. Shport and Gregory Johnson (English, Louisiana State Univ., 260-G Allen Hall, Baton Rouge, LA 70803, ishport@lsu.edu)

In English, monosyllabic function words (*them*, *in*) are prosodic clitics, but the prosodic status of multisyllabic function words (*whenever, everybody*) is not well understood. We compared fundamental frequency (F0) patterns in function and lexical compounds to determine whether the words

formation process, compounding, is associated with a certain prosodic template. F0 was examined because of vowel-intrinsic differences in duration and intensity, the other two correlates of prominence. Four speakers of Appalachian English from Kentucky read sentences with words of three types in the sentence-medial position: two relative pronouns (*wh**at**ever*, ***e**ver-wh**at***), two quantifiers (***e**very**o**ne*, ***e**very**o**ne*), and six lexical words (e.g., *w**all**fl**o**wer*, ***e**vergr**ee**n*). F0 ratios between stressed vowels in two morphemes of each word were calculated. The results showed that the ratios were higher in lexical compounds than in quantifiers and in free relative pronouns, which were not different from each other. These results suggest a pattern of the first-morpheme (left-constituent) prominence in lexical words, similar to previous reports on adjective + noun compounds, and a pattern of the second-morpheme (right-constituent) prominence in function words, similar to morphologically complex but non-compound words. The proposed right-prominence prosodic template for multi-morphemic function words is discussed in relation to phrase-level accents and boundary tones.

5aSC34. Where the skies are not Cl/aʊ/dy all day: A pilot study of /aʊ/ production of speakers in rural Kansas. Matthew J. Champagne (English, North Carolina State Univ., Rm. 204 Thompkins Hall, 2211 Hillsborough St., Raleigh, NC 27603, mjchampa@ncsu.edu)

This study examines cross-generational /aʊ/ production in rural, female speakers from Dickinson County, Kansas. Acoustic analysis of nuclei and glides were BARK normalized for cross-speaker, cross-generational comparison. This study finds older and younger speakers show similar nucleus advancement and glide direction.

5aSC35. Methods for noise reduction in a legacy speech corpus. Lisa Lipani, Yuanming Shi, Joshua McNeill, and Margaret E. Renwick (Univ. of Georgia, 142 Gilbert Hall, Athens, GA 30602, llipani@uga.edu)

The Digital Archive of Southern Speech is an audio corpus featuring interviews conducted from 1968 to 1983, with speech from 30 female and 34 male southern speakers, totaling 372 h of audio data. However, automated analysis of this data has been made difficult by background noise in this legacy corpus, originally recorded on reel-to-reel tape and later digitized to .wav format. In this paper, we compare the effect of noise reduction techniques on the acoustic signal and evaluate their effect on acoustic speech data. We use Praat to detect the quietest silence (measured using root-mean-square amplitude) in each sound file. The audio data contain silences that lack background noise (e.g., due to anonymization procedures), but these are excluded from selection. Each quietest silence is used to create a "noise profile," which is removed from the audio using a scripted noise removal procedure in both Audacity and SoX. The success of each procedure is assessed with three-way comparisons of the amplitude of silences in uncleaned and cleaned audio, and vowel plots made with formant values extracted from uncleaned and cleaned audio. It is predicted that successful noise reduction will reduce the number of outliers occurring in F1, F2 space.

5aSC36. An articulatory analysis of asymmetrically confusable consonants. Ian Calloway (Linguist., Univ. of Michigan, 400 Lorch Hall, 611 Tappan Ave., Ann Arbor, MI 48109, iccalloway92@gmail.com)

Acoustic similarity and articulatory similarity do not always co-occur; a narrow range of acoustic outcomes can sometimes correspond to a comparatively wide range of articulatory parameters (Stevens, 1989). The articulatory parameters associated with a narrow window of acoustic events occasionally straddle a category boundary—some consonants (e.g., /t/ and /k/ in front vowel contexts) show acoustic (and perceptual) similarity with one another, despite differences in active articulator or place of articulation (Plauché, 2001). This study utilizes a corpus of vocal tract MRI (Sorensen *et al*., 2017) to relate the spatial dynamics of productions of /p/, /t/, /k/, /f/, and /θ/ to their acoustic properties. This analysis offers insight into why articulatorily dissimilar productions can show increased spectral similarity and how phonetic context conditions this similarity. For each segment production, five video frames were extracted—one frame before constriction release, and four after release. From each frame, a 30-point cross-sectional area function of the vocal tract airway was generated. Vocal tract parameters associated with the spectral properties of frication, aspiration, and stop bursts were analyzed. In phonetic contexts favoring misidentification, confusable segment pairs show greater similarity in vocal tract regions anterior to the primary constriction.

5aSC37. *Kyoo*, what an odd-sounding word! Acoustic analyses of a Cajun interjection. Lauren V. Vidrine and Irina A. Shport (Louisiana State Univ., 5151 Highland Rd., Baton Rouge, LA 70808, lvidri5@lsu.edu)

The interjection *kyoo* is used in English and French spoken by Cajun heritage speakers in Louisiana to express surprise. Cajun and non-Cajun speakers alike comment that *kyoo* sounds "weird," as if it has some non-English characteristics. These perceptions may stem from Cajun French influence on Cajun English. Specifically, nasalized vowels and unaspirated stops are reported to occur in this dialect, more frequently in older than younger speakers. This case study investigated *kyoo* productions in two groups of Cajun English speakers to determine whether the word conformed to French-influenced sound patterns. Acoustic analyses showed that despite speaker auditory perceptions, the *kyoo* vowel was not nasalized as compared to other English words with oral and nasal codas. The spectral quality of this vowel was most similar to /ɔ/. Furthermore, voice onset time of the initial /k/ was not consistent with that of unaspirated stops. These results suggest the perception of anomalous sounds in this interjection may not be attributed to the acoustic characteristics indicative of French influence. Alternative explanations may include relatively long vowel duration due to speakers' enthusiasm to perform Cajunness, palatalization of the initial stop followed by the open-mid back vowel, or simply non-standard nature of *kyoo* stereotyped by speakers.

5aSC38. Definite determiner realization in the Philadelphia neighborhood corpus. Jennifer B. Arlin (Linguist., Univ. of Pennsylvania, 3401 Walnut St., Ste. 300, C Wing, Philadelphia, PA 19104-6228, jarlin@sas.upenn.edu)

Systematic variation in the pronunciation of the definite determiner (orthographic *the*) is well-known; the general rule is that preconsonantal /ðə/ alternates with prevocalic /ði/. Nonetheless, widespread deviation from this rule has been noted, most recently by Meyerhoff (2018) (examining definite determiner pronunciation in various populations in New Zealand). This project studied *the* realization among a small sample of female speakers in the Philadelphia Neighborhood Corpus. All were L1 English speakers, born between 1950 and 1986 and interviewed between 1973 and 2010. The determiner was hand-coded throughout their interviews for pronunciation and for nature of the following segment (vowel- or consonant-initial, as uttered). The data were then analyzed to determine whether age or following segment influenced realization as /ðə/ or /ði/. Results indicated a high degree of adherence to the canonical rule, showing preconsonantal /ðə/ 97% of the time and prevocalic /ðə/ 18% of the time. While the rate of occurrence of prevocalic /ðə/ was generally quite low, it did vary significantly by speaker. The younger generation on average tended to use prevocalic /ðə/ slightly more often than the older generation; individual variations made it impossible to draw any conclusions about a meaningful connection between age and variation.

5aSC39. Reference speaker selection for kinematic-independent acoustic-to-articulatory-inversion. Narjes Bozorg and Michael T. Johnson (Elec. and Comput. Eng., Univ. of Kentucky, 1608 University Court, Unit C312, Lexington, KY 40503, narjes.bozorg@uky.edu)

This paper investigates the most effective reference speaker set for the Parallel Reference Speaker Weighting (PRSW) algorithm for kinematic-independent acoustic-to-articulatory inversion. To obtain the adaptation weights for estimating the articulatory model, different reference speaker accent types and quantities have been acquired. The reference speaker sets have been selected not only based on their performance in speaker-dependent kinematic-inversion but also based on the type of accent. The experiments have been conducted on parallel Acoustic-Articulatory data, the Marquette Electromagnetic Articulography corpus of Mandarin Accented English (EMA-MAE) consisting of 20 native English speakers and 19 native Mandarin speakers of English. A comparison is made between different types of target speakers and reference speakers with results indicating that the accuracy of the adapted model increases when we select balanced distributed accents of English and lower number of speakers.

5aSC40. Individual differences in the production of prosodic boundaries in American English. Jiseung Kim (Univ. of Michigan, 440 Lorch Hall, Ann Arbor, MI 48109, jiseungk@umich.edu)

This study investigates individual differences in the weighting of phonetic properties in the production of prosodic boundaries in American English. The motivation of the study is to inform understanding of individual speaker variation and its accommodation in the representation of prosodic structure. In an acoustic study, 32 speakers produced eight sentence pairs differing in type of boundary (Intonational Phrase (IP) boundary versus Word boundary). Pause duration, phrase-final lengthening (three syllables before the boundary), phrase-initial lengthening (one syllable after the boundary), and pitch reset were examined. The results of a series of statistical analyses showed substantial individual differences in (1) which segmental and suprasegmental properties speakers phonetically modulated to produce IP boundaries and (2) the scope and the degree of such modulations. In addition, the results suggest that there seems to be no apparent relationship between how speakers modulated boundary-adjacent syllable durations and whether and how they used two other acoustic correlates for IP boundary, namely, pause duration and pitch reset. The current models of prosodic structure need to accommodate the fact that individuals may vary significantly while systematically modulating the acoustic correlates relevant for encoding a prosodic contrast.

5aSC41. Semantic predictability and the use of creaky voice in female speakers. Stefania Marchitelli (Communicative Sci. and Disord., New York Univ., 6 Old Homestead Way, Albertson, NY 11507, sm6276@nyu.edu) and Susannah V. Levi (Communicative Sci. and Disord., New York Univ., New York, NY)

The purpose of this study was to investigate the prevalence of creaky voice in sentence-final position as a function of semantic predictability of the final word. Creaky voice is maligned in the media and often claimed to be less intelligible than normal phonation. A recent study finds some evidence to support this claim by examining intelligibility of single words. If speakers were concerned about intelligibility of their speech, they may be less likely to use it in sentences with little semantic support (e.g., "Mr. Black knew about the pad" compared to "Tear off some paper from the pad"). In the current study, 11 young female speakers without any vocal pathologies produced sentences from the Speech Perception in Noise (SPIN) test. Fourteen final words that appeared in both high and low semantic predictability sentences were selected for analysis. Three outcome measures were examined for these final words: presence versus absence of creaky voice, duration of creaky voice, and type of creaky voice. Contrary to our expectations, the results indicated that semantic support does not significantly predict the existence, amount, or type of creaky voice in young female speakers.

5aSC42. Transfer in speech motor learning: The role of voicing. Hung-Shao Cheng (Communicative Sci. and Disord., New York Univ., 2559 35th St. Apt. 2L, Astoria, NY, hscheng@nyu.edu) and Adam Buchwald (Communicative Sci. and Disord., New York Univ., New York City, NY)

Previous studies have demonstrated that American English speakers can improve their production of phonotactically illegal onset clusters (e.g., DBEEGO) after structured practice. However, the nature of what is learned remains incompletely understood. We use a transfer paradigm to address this question by examining performance on trained and untrained novel consonant sequences. In particular, we investigated whether the differences between voiced and voiceless stop-stop clusters (e.g., /gd/ vs. /kt/) influences transfer of learning, hypothesizing that the voiced clusters involve more complex motor control. Forty native speakers of American English practiced nonwords beginning with either voiced (/gd/, /db/, /gb/) or voiceless (/kt/, /kp/, /tp/) stop-stop onset clusters. All participants were tested on both types of clusters at baseline (prior to practice) and in two retention sessions (20 minutes (R1) and 2 days (R2) after practice). Blinded coders rated cluster accuracy based on presence of a vowel in the acoustics. Preliminary results (n = 10) indicate a trend of bi-directional transfer, with participants in both practice conditions exhibiting improved accuracy for both trained and untrained clusters.

5aSC43. Studying the rate of velar elevation across different vowel contexts in normal speech using high speed nasopharyngoscopy. Hedieh Hashemi Hosseinabad (Commun. Sci. and Disord., Eastern Washington Univ., 310 N Riverpoint Blvd., Box B, Spokane, WA 99202-1609, hhosseinabad@ewu.edu), Liran Oren (Univ. of Cincinnati, Cincinnati, OH), Ann W. Kummer (Cincinnati Childrens Hospital, Cincinnati, OH), and Winter Taite (Washington State Univ., Spokane, WA)

Velum has a range of positions across different speech segments, with the lowest velum position for nasal consonants, a high (closed) position for obstruent consonants, and a range of positions in the middle for sonorant consonants and vowels varying according to constriction degree. Vowel environment has a considerable influence on the rate of velum closure. Changes in the rates of velar positioning during production of vowels in non-nasal speech (H-words) was studied in seven typically speaking adults with general American dialect and normal oral-nasal resonance. The participants were scoped using a Phantom Miro 310 high-speed video camera (Image acquisition rate of 5000 fps) connected to a flexible scope. Measurements were taken simultaneously with capturing acoustic data. The data suggested that velum tends to have a higher elevation point for vowels with higher degree of constriction in the oral cavity like /i/. Further results will be discussed.

5aSC44. Relative influences of information structure and utterance-final position on the prosodic implementation of nuclear pitch accents. Eleanor Chodroff and Jennifer Cole (Linguist., Northwestern Univ., 2016 Sheridan Rd., Evanston, IL 60208, eleanor.chodroff@gmail.com)

The phonological and phonetic realization of a nuclear pitch accent has been claimed to reflect aspects of its information structure (IS). As the rightmost accented word in an intonational phrase, the nuclear pitch accent often co-occurs with utterance-final position, which in American English, is often cued by prosodic means such as creaky voice and domain-final lengthening. The present study investigated the relative influence of IS and utterance-final position on the prosodic implementation of words in nuclear position. The IS of an object noun phrase occurring in nuclear position was manipulated to be given, accessible, new, or contrastive relative to a parallel object noun in the preceding sentence. The critical object noun occurred in utterance-final position in experiment 1 and in non-final position and preceding a semantically vacuous syntactic phrase in experiment 2 (e.g., "that was there," "for it). Given that contrastive information significantly influenced the prosodic implementation of the object noun in both experiments with respective reduction and enhancement effects, but utterance-final position nevertheless regulated the particular phonetic instantiation. While IS modulated the degree of creakiness, duration, and intensity in final position, IS conditions in non-final nuclear position modulated the type of f0 contour and duration.

5aSC45. The relationship between duration and spectral position in white southern US speech. Jon Forrest (Linguist., Indiana Univ., 830 Ballantine Hall, Bloomington, IN 47405, jonforr@iu.edu)

Previous research on regional differences in vowel quality and duration found that white Southern speakers make less of a distinction between high and mid tense-lax vowel pairs in both quality and duration than speakers from other regions (Kendall *et al*., 2014). However, the effect of duration on vowel quality in Southern speech has not been explored to the same degree. This study examines duration, vowel quality (in F1-F2 space), and their relationship. Data come from 80 h of self-recorded and interview speech from 17 white Southern natives with varying degrees of the Southern Vowel Shift (SVS). Measurements for F1 and F2 were extracted at vowel nucleus (25% duration) for the /e/-/ɛ/ and /i/-/ɪ/ pairs both implicated in the SVS. Formants were Lobanov-normalized and both duration and vowel quality were examined with mixed-effects linear regression. Results show that most speakers maintain a durational distinction between tense-lax pairs, but the effect of duration on vowel quality varies greatly from speaker to speaker. Those speakers who exhibit higher degrees of SVS shift show individual slopes for duration in the opposite direction than less-Southern counterparts. First, these results demonstrate that controlling for individual differences in duration is important for properly analyzing Southern speech corpora.

Second, they suggest that duration, vowel quality, and their relationship all play a role in regional distinction.

5aSC46. Acoustic characteristics of aspirated fricatives in a Tibeto-Burman language. Maureen Hoffmann (Dept. of Linguist., Univ. of Arizona, 402 S Reisner Dr., Bloomington, Indiana 47401, mhoffm@email.arizona.edu)

Aspirated fricatives are typologically rare, though they are relatively more common in Asia (Jacques, 2011). Of the 2155 languages in the PHOIBLE Online database of phonological segments, only 7 are reported to have distinctive fricative aspiration (Moran *et al*., 2014). This paper examines the acoustic properties of aspirated fricatives in Matu, an underdocumented Kuki-Chin (Tibeto-Burman) language spoken in Chin State, Burma (Myanmar). Matu contrasts unaspirated alveolar fricative /s/ with aspirated alveolar fricative /s^h/. Aspirated alveolar fricatives are also found in other Chin languages and have been reconstructed for Proto-Kuki-Chin (VanBik, 2009, p. 186). The data were recorded with Matu-speaking refugees living in Indiana, U.S. and are analyzed using durational and spectral measures. This research expands literature on an uncommon—and reportedly diachronically unstable (Jacques, 2011)—phonemic contrast while increasing documentation of an understudied language. Jacques, G., "A panchronic study of aspirated fricatives, with new evidence from Pumi," *Lingua*121, 1518–1538 (2011). and Wright, R.(eds). 2014. *PHOIBLE Online*, edited by S. Moran, D. McCloy, and R. Wright (Max Planck Institute for Evolutionary Anthropology, Lepzig, 2014). VanBik, K., "Proto-Kuki-Chin: A reconstructed ancestor of the Kuki-Chin languages," *STEDT Monograph Series #8* (University of California, Berkeley, CA, 2009).

5aSC47. A comparison of four vowel overlap measures. Matthew C. Kelley and Benjamin V. Tucker (Linguist., Univ. of Alberta, 4-23 Assiniboia Hall, Edmonton, AB T6G 2E7, Canada, mckelley@ualberta.ca)

Measures of vowel overlap to explore the acoustic similarity between proposed and existing vowel categories. They typically compare F1 and F2, and sometimes duration. In the present study, we investigate four methods of quantifying vowel overlap: the spectral overlap assessment metric (Wassink, 2006), the *a posteriori* probability-based metric (Morrison, 2008), the vowel overlap assessment with convex hulls method (Haynes and Taylor, 2014), and the Pillai score as used by Hay *et al*. (2006). Based on the data for /i/ and /ɪ/ in the dataset of Hillenbrand *et al*. (1995), we used Monte Carlo style simulations and repeated subsampling to assess each method. We examined both the two-dimensional (F1 and F2) and three-dimensional (F1, F2, and duration) versions of the methods. We took the methods' outputs as accurate if they produced values close to expected target values for each type of simulation, and we took the results as precise if there was little spread among the output values. The results suggest that the *a posteriori* probability-based metric is the most generally applicable, while the Pillai score should be used in scenarios where sensitivity to complete overlap is needed or where data cannot be said to be normally distributed.

5aSC48. Acoustic differences between normally phonated and whispered speech. Nichole Houle and Susannah V. Levi (New York Univ., 665 Broadway, New York, NY 10012, nh1473@nyu.edu)

Whispered speech is different from normally phonated speech in more than just lack of vocal fold vibration. Previous research suggests that speakers also modify their speaking rate and formant frequencies. The extent of these differences may depend on speaker gender, but this has not been studied in American English. We examined differences in duration and acoustic vowel space between normally phonated and whispered speech. We recorded 17 ciswomen, 11 cismen, and 10 transwomen producing hVd words in both normally phonated and whispered speech. Formant frequencies for /æ/, /ɪ/, /ɑ/, and /u/ were bark-transformed and vowel space area was calculated. The results indicated differences in the formants across the two speaking conditions, both in the absolute shift of formant values and in the size of the vowel space. In addition, differences in speaking rate (measured as the duration of the /hV/ portion) also showed differences between the two speaking conditions across the three speaker groups.

5aSC49. Temporal structures of English and Mandarin running speech. Can Xu, Mingshuang Li, Chang Liu (Dept. of Commun. Sci. and Disord., The Univ. of Texas at Austin, Austin, TX 78712, canxu@utexas.edu), and Sha Tao (National Key Lab. of Cognit. Neurosci. and Learning, Beijing Normal Univ., Beijing, China)

A number of studies have found that temporal envelope cues are significant for both English and Mandarin speech perception. However, native English and Mandarin speakers appear to differ in abilities to use these cues in speech recognition. The current study thus aims to investigate whether the temporal envelopes of English and Chinese running speech have any significant difference. Conversational speech of 16 males and 16 females from the United States and mainland China was recorded. The temporal envelope and long-term spectrum were analyzed and compared across the two groups of speakers. Results showed that in the temporal modulation domain, English speech had a peak at around 3 Hz, while for Chinese speech, the peak was observed relatively steadily from 3 to 5 Hz. Moreover, English speech possibly contained significantly longer and deeper temporal troughs to make use of than Chinese. [Works supported by the China National Natural Science Foundation (31628009).]

Session 5aUW

Underwater Acoustics: Underwater Signal Processing and Applications

David F. Van Komen, Chair
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Contributed Papers

9:00

5aUW1. Development of an in-air circular synthetic aperture sonar system as an educational tool. Thomas E. Blanford, John D. McKay, Daniel C. Brown, and Joonho D. Park (Appl. Res. Lab., The Penn State Univ., State College, PA 16804, teb217@psu.edu)

Synthetic aperture sonar (SAS) is an underwater acoustic imaging technique that is used to generate high quality imagery through the coherent combination of signals measured on a moving platform. The practical challenges of underwater experimentation and the lack of publicly available data sets make it difficult to teach SAS processing to students using experimental data. These challenges are compounded by the complicated signal processing that is required to compensate for the unwanted platform motion that is common in field data. This presentation will detail the development of an in-air circular SAS system using commonly available laboratory equipment. By operating in air and using a circular geometry many of the challenges that students would otherwise encounter in SAS processing are either well controlled or completely eliminated. Imagery collected on the system will be displayed to demonstrate how meaningful data can be generated using a simple set of equipment. A number of applications of the system as a tool to teach array signal processing, pulse compression, and imaging concepts will be discussed as well.

9:15

5aUW2. Evaluation of underwater acoustic images obtained by the early stage monotone pulse-echo Synthetic Aperture Sonar. Kyungmin Baik (Ctr. for Medical Convergence Metrology, Korea Res. Inst. of Standards and Sci., Daejeon 34113, South Korea, kbaik@kriss.re.kr), Seung-Soo Park (SonarTech, Busan, South Korea), and Joong Eup Kye (Ministry of Trade, Industry and Energy, Seoul, South Korea)

Synthetic Aperture Sonar (SAS) is a side-looking underwater acoustic imaging sonar that can obtain higher resolution images than those by the conventional Side Scan Sonar (SSS). Due to its high resolution images, it can be applied to various fields of studies from military to civilian purposes. Republic of Korea recently has launched a research project developing the prototypes of SAS being operated in a few hundreds kHz of acoustic signals. This project adopted the towfish as the SAS platform that are to be towed under a few tens of water depth, which has a price advantage over Autonomous Underwater Vehicle (AUV), but gives unstable motion. It also adopted the monotone pulse-echo mode as transceiver method of the prototypes that gives relatively simpler implementation of the data acquisition module although it gives inferior SNR to the chirp mode. In the current study, the underwater acoustic images of the protype SAS taken both in the fresh water and offshore of Korea are to be shown. Current study also shows the evaluation method of image resolutions using test targets simulating point scatterers. Resulting images are to be compared with the images by the conventional SSS through the evaluation of the resolution. As is well known, although SAS generated clearer underwater images than SSS images, phase uncertainty of the array is critical factor determining the image resolution of SAS that is heavily degradated by the unwanted motion of the SAS platform.

9:30

5aUW3. Analysis of a ray-based blind deconvolution algorithm on ships of opportunity in the Santa Barbara Channel. Nicholas C. Durofchalk (Mech. Eng., Georgia Inst. of Technol., 771 Ferst Dr. NW, Rm. 131, Atlanta, GA 30332, ncd001@lvc.edu), Xuedong Zhang (Inst. of Acoust., Chinese Acad. of Sci., Beijing, China), and Karim G. Sabra (Mech. Eng., Georgia Inst. of Technol., Atlanta, GA)

The ray-based blind deconvolution (RBD) technique for ocean waveguides estimates both the Channel Impulse Response (CIR) and the unknown waveform radiated by some source of opportunity measured on an array of hydrophones using only knowledge of the array geometry and the local sound speed. This method has been shown to be well suited for estimating CIRs in environments with water column depths of ~100 m and the estimated CIRs have been successfully used in conjunction with other techniques, such as matched field processing or waveguide invariant based approaches, for source localization, bottom parameter inversion, and other related studies. With the recent 2016 at-sea passive noise experiment in the Santa Barbara Channel (SBC), plenty of processing remains to be done; however, the RBD's performance and robustness in such an environment (~580 m depth, downward refracting profile) is not well documented. Here, we seek to investigate the feasibility and effectiveness of the RBD method in estimating CIRs from ships of opportunity in the SBC in terms of the assumptions of the technique, application to data, and numerical simulation.

9:45

5aUW4. A FNN for source range and ocean environment classification using time-domain features. David F. Van Komen (Phys. and Astronomy, Brigham Young Univ., N283 Eyring Sci. Ctr., Provo, UT 84602, david.vankomen@gmail.com), David P. Knobles (KSA, LLC, Austin, TX), Tracianne B. Neilsen (Phys. and Astronomy, Brigham Young Univ., Provo, UT), and Mohsen Badiey (Univ. of Delaware, Newark, DE)

Acoustic source ranging in an uncertain ocean environment is a complicated problem, though classification and regression-based machine learning algorithms show promise. A feedforward neural network (FNN) has been trained to do either classification or regression on both the source-receiver range and environment type using extracted time-domain features. Time waveforms are generated to simulate signals received at different ranges in three different environments with a sandy, muddy, or mixed sediment bottom. Four features are extracted from these waveforms: peak level, integrated level, signal length, and later decay time. These four features are used to train FNN for both classification and regression of range and environment type, and the results are compared to a network trained on the time waveforms. For small amounts of training data, the extracted features provide a higher accuracy than the full waveform. Thus, physics-based feature selection via preprocessing can lead to fairly accurate results when using a FNN with small datasets. These results lay a foundation for comparisons to the more computationally expensive convolutional neural networks. [Work supported by the Office of Naval Research.]

10:00

5aUW5. A waveform-based convolutional neural net for source range and ocean environment classification. David F. Van Komen, Tracianne B. Neilsen (Phys. and Astronomy, Brigham Young Univ., N283 Eyring Sci. Ctr., Provo, UT 84602, david.vankomen@gmail.com), David P. Knobles (KSA, LLC, Austin, TX), and Mohsen Badiey (Univ. of Delaware, Newark, DE)

Neural networks learn features that are useful for classification directly from a source, such as a recorded signal, which removes the need for feature extraction or domain transformations necessary in other machine learning algorithms. To take advantage of these benefits and have a finer temporal resolution than a spectrogram, we built a one-dimensional convolutional neural network to classify source range and ocean environment from a received signal. The neural network was trained on simulated signals generated in different environments (sandy, muddy, or mixed-layer sediment layers) for several range classes. We found significant potential in a neural network of this type, given a large amount of varied training samples for the network to learn important features to make range and environment predictions. This type of network provides an alternative for frequency-domain learning and is potentially useful for impulsive sources. Benefits of using a time-domain envelope are also explored. Success in the time domain also reduces the computational requirements of conversion to frequency domain and increases the temporal resolution, which might be beneficial for real-time applications. [Work supported by the Office of Naval Research.]

10:15

5aUW6. Investigating parameter importance for different ocean environments using Fisher Information. Makenzie B. Allen, David F. Van Komen, Tracianne B. Neilsen, Mark K. Transtrum (Phys., Brigham Young Univ., N283 ESC, Provo, UT 84602, allenmakenzie1427@gmail.com), and David P. Knobles (KSA, LLC, Austin, TX)

In machine and deep learning, we often seek a simple and effective model. Overly complex models may be difficult to train and make inaccurate predictions. One way to find an effective model is to consider the relative impact of parameters on predictions as seen in the Fisher Information. The applicability of the Fisher Information is shown using numerically modeled transmission loss as a function of frequency for different range-independent ocean environments. The sensitivities to source-receiver range and depth and environmental parameters are quantified by calculating the Fisher Information. First, the Jacobian matrix of partial derivatives of transmission loss with respect to each of the model's input parameters is obtained, then the Jacobian matrix is used to calculate the Fisher Information matrix. An eigenvalue decomposition of the Fisher Information matrix shows that this system is "sloppy," because it exhibits an exponential hierarchy of parameter importance. In many cases, only a small number of parameters are relevant for explaining the model output but the impact of individual geoacoustic parameter varies with both environment and frequency. Our results have implications for learning algorithms and data collection methods while elucidating the relevant physics for different conditions. [Work supported by the Office of Naval Research.]

10:30–10:45 Break

10:45

5aUW7. Replicating a below-band linear field in a refracting sound channel via a caustic-corrected autoproduct. David J. Geroski (Randall Lab., Appl. Phys., Univ. of Michigan–Ann Arbor, 450 Church St., Ann Arbor, MI 48109, geroskdj@umich.edu) and David R. Dowling (Mech. Eng., Univ. of Michigan, Ann Arbor, MI)

Frequency difference source localization methods have achieved some success in uncertain underwater environments by taking advantage of the frequency difference autoproduct—a quadratic product of two complex field amplitudes at different frequencies but from the same location and recorded signal. The phase of the frequency difference autoproduct is less sensitive to unknown propagation complexities than that of the in-band field from which it is derived. The noted localization success arises in some technologically relevant scenarios when the frequency difference autoproduct at least partially mimics a genuine acoustic field at the difference of the two frequencies. However, the nonlinearity inherent in the autoproduct can lead to salient and even counter-intuitive differences between it and a genuine below-band field in the same environment. This presentation explores methods for correcting the phase differences that arise between autoproducts and genuine fields in refracting multipath environments that lead to the formation of caustics. This presentation illustrates the effectiveness of utilizing these methods to localize sources using propagation simulations in a refracting environment, and 200 to 300 Hz PhilSea10 propagation data (Worcester *et al.*, 2013) collected in a deep-ocean sound channel at source-array ranges of hundreds of kilometers. [Work supported by ONR.]

11:00

5aUW8. Block-sparse compressive localization for incipient tip vortex cavitation noise. MinSeuk Park, Woojae Seong (Underwater Acoust. Lab., Seoul Nat. Univ., 36-212,1, Gwanak-ro, Gwanak-gu, Seoul 08826, South Korea, mindal2@snu.ac.kr), Youngmin Choo (Sejong Univ., Seoul, South Korea), and Yongsung Park (Seoul Nat. Univ., Seoul, South Korea)

Marine propeller cavitation is a dominant noise source of ships. Thus, localizing the cavitation noise source is essential for subsequent remedy. Given that incipient tip vortex cavitation (TVC) noise radiates in all directions as a monopole source and a few noise sources exist in the vicinity of the propeller, the localization problem can be considered as a sparse signal reconstruction problem. Compressive sensing (CS) based localization technique utilizes a sparsity promoting constraint and solves the localization problem efficiently with high resolution. Block-sparse CS, based on block-sparsity, is adopted to process multiple frequency components of the sources coherently. Block-sparse CS localization of TVC shows superior performance with high resolution compared to the conventional CS based incoherent multiple frequency processing. To demonstrate the performance of the block-sparse CS localization, both synthetic and real cavitation tunnel experiment data are used.

11:15

5aUW9. Application of simulated annealing particle swarm optimization in underwater acoustic positioning optimization. JiangQiao Li (Systems Eng. Res. Inst. of CSSC, Beijing, China), Juan Hui (Underwater Acoust., Harbin Eng. Univ., Harbin, Heilongjiang 150001, China, huijuan@hrbeu.edu.cn), Li Huangpu (Systems Eng. Res. Inst. of CSSC, Beijing, China), and Xianzhong Bu (Harbin Eng. Univ., Harbin, China)

In the calculation of underwater acoustic positioning, the errors of element position measurement, time delay measurement, attitude accuracy and sound velocity measurement will lead to the calculation errors of final positioning solution. The optimization method of solution is also one of the key technologies of location solution. The traditional statistical methods of solution mostly use arithmetic average optimization method and Newton iteration method. In this paper, the particle swarm optimization method based on simulated annealing is used to improve the estimation accuracy of location solution. The effectiveness of this method is verified by computer simulation and comparative analysis. First, the spherical intersection method of synchronous positioning and the hyperbolic intersection method of asynchronous positioning are introduced in this paper. Then, the method of measuring time delay and filtering signal is introduced. Finally, another factor affecting positioning accuracy is discussed. The method of solving nonlinear equation is discussed. By comparing the root mean square error of three methods under different signal-to-noise ratios, the signal-to-noise ratio is obtained. The accuracy of the three algorithms is almost the same when compared with each other, but at low SNR, the simulated annealing particle swarm optimization (SA-PSO) algorithm can calculate more accurate positioning solutions.

11:30

5aUW10. Passive underwater acoustic tags with curved symmetry for navigation and information encoding. Aprameya Satish, David Trivett, and Karim G. Sabra (Mech. Eng., Georgia Inst. of Technol., Woodruff School of Mech. Eng., 801 Ferst Dr., Atlanta, GA 30313, aprameya.satish@gatech.edu)

Passive acoustic beacons built of horizontally stratified materials have been designed in previous literature to assist in the navigation of autonomous underwater vehicles (UAV) equipped with SOund Navigation and Ranging (SONAR) instrumentation. These beacons reflect a characteristic acoustic signature which can be detected by the AUV as acoustic backscattering upon tag insonification. Currently, only backscattering from acoustic waves normally incident on a beacon can be detected by the AUV due to the beacon's planar geometry. To address this issue, this paper proposes the design of passive acoustic beacons with curved symmetry, whose acoustic backscattering is the same irrespective of the angle of source incidence. Simulation and experimental results are discussed for beacons made of concentric spherical shells as a proof of concept.

11:45

5aUW11. Measurement of arm length difference of interferometric fiber-optic hydrophone using extra-carrier modulation and interference fringe counting method. Jun Zhang, Yi Chen, Han Zhao, and Jiaheng Wang (Hangzhou Appl. Acoust. Res. Inst., No. 82, Guihuaxi Rd., Fuyang District, Hangzhou, Zhejiang 311400, China, 13957123130@139.com)

Due to the characteristics of low loss, passivity, and long-distance transmission, interferometric fiber-optic hydrophones and their arrays have been widely used in engineering detection applications. The arm length difference is one of its main performance parameters. A system for measuring of arm length difference using extra-carrier modulation and interference fringe counting method is introduced in detail. The propagation process of optical signal in the fiber-optic hydrophone is described. The mathematical expression of the phase of interferometric optical signal intensity caused by external carrier is given and analyzed. The expression of arm length difference and its evaluation of measurement uncertainty are obtained. Experimental study on measurement of arm length difference is developed. Both theoretical analysis and experimental results show that the product of the driving voltage of the fiber stretcher and the arm length difference has fixed value. Combining the known arm length difference value and the carrier driving voltage of the reference interferometer, the arm length difference of the hydrophone to be measured can be calculated with the value of its carrier driving voltage accurately. The uncertainty of measurement of the device and method described in this paper is better than 0.5%. The measuring range is 0.1 m to 500 m.