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The Acoustical Society of America

ECHOES

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Voice Quality: What Is Most Characteristic About "You" in Speech

by Ingo R. Titze and Brad H. Story

We send multiple messages when we speak. Some are linguistic and some paralinguistic, meaning that they are independent of the words that we utter. Such paralinguistic messages concern our health, our mood, our genetic makeup, and our upbringing. Many of them are encoded in voice quality, which in the most general sense is everything in the acoustic signal other than overall pitch, loudness, and phonetic contrast (vowels and consonants).

Descriptions of voice quality have traditionally consisted of qualitative terms such as warm, shrill, twangy, creaky, shrieky, breathy, yawny, gravelly, hoarse, ringing, dull, nasal, resonant, rough, and pressed. While commonly used in both clinical and non-clinical situations, the acoustic and articulatory correlates of these terms have not been well defined. In comparison, the characteristics of *vocal registers* have been somewhat better defined and are often given the generally accepted labels of modal, fry, and falsetto in speech, and chest, head (or mixed), falsetto and whistle in singing.

Work is now ongoing to address a few of these voice qualities on a physiologic and acoustic level. Much of this work is supported by the National Institute for Deafness and Other Communication Disorders, which believes that better treatment and care of the human voice can be achieved if clinicians can discriminate these vocal qualities and relate them to abnormality.

Our own efforts have been directed toward a better understanding of vocal tract shapes that, together with laryngeal (voice source) adjustments, produce certain voice qualities. Magnetic resonance imaging (MRI) has been our primary tool for studying the vocal tract shape. Images are acquired while a speaker repeats a specific vowel or consonant over and over again. Subsequent image analysis is used to assess the cross-sectional area of the airway along its extent from the larynx to the lips, effectively creating a continuously-variable tubular representation of the vocal tract shape. At this point, four speakers have been imaged with this method. The first two (a male and female) produced most of the vowels and consonants of American English while the second set of speakers (another male and female) were asked to produce only four vowels, but with four different voice qualities.

A statistical analysis of each speaker's set of vocal tract shapes (for the different vowel or quality conditions) and calculations of frequency response functions, have revealed that the average vocal tract shape produces acoustic characteristics that seem to be unique to both the speaker and to the particular voice quality used during the image collection. This average shape is similar to that expected for a neutral or *schwa* vowel /ə/, and roughly produces the vowel sound heard when speaking "uh-huh." Figures 1a and 1b show average vocal tract shapes, in tubular form, for a male and female speaker, respectively. Note that this representation results from plotting the measured cross-sectional areas as equivalent circular elements. What makes these average shapes acoustically "neutral" is that their lower formant (resonance) frequencies (specifically F1, F2, and F3) are nearly equally spaced.

Statistical analysis of the tract shape has also suggested that all other vowel shapes (and many consonant shapes) are linear combinations of the neutral shape and three eigen-shapes. These eigen-shapes, similar to eigen modes in vibration theory, can be used as orthogonal building blocks (with proper coefficients) to construct the vocal tract shapes used in any given spoken language. Thus, an interesting dichotomy arises between the shaping of the vocal tract airway for linguistic versus paralinguistic messages: the neutral shape is used primarily to code

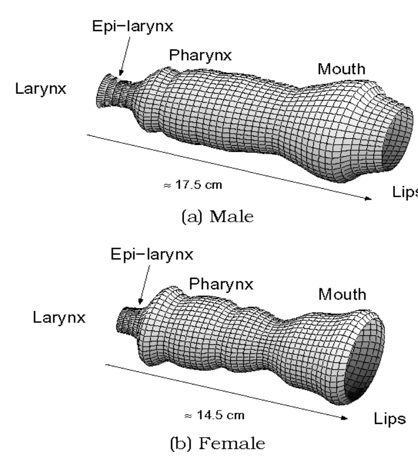

Figure 1. Tubular representations of the neutral (average) vocal tract shapes for a male and a female.

continued on page 4

We hear that...

- **Clive L. Dym** received the Fred Maryfield Design Award from the American Society for Engineering Education at its annual conference in Montreal on June 19. Clive, an ASA Fellow, is Fletcher Jones Professor and Chair of the Department of Engineering at Harvey Mudd College.
- **Sean Wu** has been named to the DeVlieg professorship in Mechanical Engineering at Wayne State University.
- **Sabih Hayek**, ASA Fellow, has retired after 37 years at Penn State University.
- The *New York Times* of September 16, 2002 carried an obituary of **Robert E. Apfel**, ASA Fellow and former President , who died from cancer August 1 at age 59. Apfel, a professor of engineering at Yale University, devoted much of his career to the study of liquids, including surface tension, acoustic levitation of liquid drops. He also used ultrasound to probe tissues and cells. He founded and edited ASA's electronic journal *Acoustics Research Letters Online (ARLO).* Culminating his many honors was the ASA Gold Medal awarded June 5 at the 143rd meeting in Pittsburgh.
- The new **standard on classroom acoustics** (ANSI S12.60-2002) is now available at the ASA Standards Store <http://asa.aip.org>. The criteria, requirements, and guidelines of this Standard are keyed to the acoustical qualities needed to achieve a high degree of speech intelligibility in learning spaces, according to Paul Schomer, ASA's Standards Director. If followed, this Standard removes acoustical barriers to learning.
- The Acoustical Foundation of India named **Deepak K. Prasher** at the Institute of Laryngology and Otology, University College, London to receive its Silver Medal in Audiology. Professor Prasher's interests range from noise effects on the auditory system to cochlear implants and speech and language acquisition.
- **Pat Kuhl** was the featured speaker at Rockefeller University's "Woman and Science" program on May 9. The audience included

500 of the most prominent New York philanthropists, including co-chairs Brooke Astor and David Rockefeller. Pat's dinner partner was Henry Kissinger (see photo). He commented to Pat that the work on language perception was not only explaining why language barriers across cultures were difficult to surmount but that similar differences in people's worldviews made diplomacy (his job) a challenging enterprise.

ECHOES

Newsletter of the Acoustical Society of America

Provided as a benefit of membership to ASA members

The Acoustical Society of America was organized in 1929 to increase and diffuse the knowledge of acoustics and to promote its practical applications.

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Best student paper awards

The following student presenters won best student paper awards at the 143rd ASA meeting at Pittsburgh:

Biomedical Ultrasound/Bioresponse to Vibration
First: Stanley Samuel, University of Michigan Medical Center
Second: Yufeng Zhou, Duke University

Musical Acoustics
First: Eric Cox, Northern Illinois University
Second: Michael Busha, Grinnell College

Physical Acoustics
First: Jin Liu, Penn State University
Second: Joseph Gladden, Penn State University

Signal Processing in Acoustics
First: Brian Rapids, Penn State University

Speech Communication
First: Miranda Cleary, Indiana University
Second: Monica Padilla, University of Southern California

Structural Acoustics and Vibration
First: Manmohan Moondra, Wayne State University
Kent Gee, Brigham Young University

Underwater Acoustics
First: Luc Lenain, University of Delaware
Second: Yi-san Lai, Massachusetts Institute of Technology

Fun in the Sun

Fun in the sun in Cancun

The first Pan-American/Iberian meeting on acoustics will take place in Cancun, Mexico December 2-6. It will combine the 144th meeting of ASA, the 3rd Iberoamerican Congress of Acoustics, and the 9th Mexican Congress on Acoustics. Approximately 1100 abstracts have been received from all over the world; this meeting promises to be a global event!

Cancun has a special attraction for acousticians from northerly climates in December. Boasting some of the world's finest beaches, it is also near the historic Mayan ruins of the Yucatan Peninsula (Chichen Itza, Uxmal, Tulum, etc.), not to mention a fine reef for snorkeling. A post-meeting excursion to Chichen Itza on December 7-8 will also include visits to Valladolid and the Balancanche Caves.

In keeping with the international character of the meeting, an opening ceremony is planned on Monday at 9:30 a.m. The ceremony will include cultural entertainment as well as greetings from the presidents of the sponsoring organizations and the meeting co-chairs. At the plenary session on Wednesday afternoon, awards will be presented by all three organizations.

Two special tutorial sessions have been scheduled: Architectural Acoustics by Neil Shaw, Rick Talaske, and Sylvio Bistafa (Monday, 2 December); and Industrial Noise Control by Samir Gerges and Brandon Tinianov (Friday, 6 December). There is no charge to meeting participants to attend. Two short courses will be presented by Bruel & Kjaer USA on Sunday, 1 December (Sound Quality Fundamentals and Noise Source Identification).

Special lectures on the History of Acoustics will continue with lectures on Origins and evolution of the developments which led to echo-Doppler duplex colorflow diagnostic methods by Donald W. Baker on Tuesday and The history of animal bioacoustics by Arthur N. Popper on Thursday.

Complimentary buffets with cash bar are scheduled for Tuesday and Thursday evenings preceding the open meetings of the technical committees. A hospitality room for accompanying persons will provide information on a full program of activities for them during the meeting days.

Ads in ECHOES?

This issue of *ECHOES* includes advertising by some of our exhibitors. We are trying this in response to a number of suggestions from members that we carry advertising. To accommodate the advertisements, we have added 4 extra pages to this issue. We have kept the advertisements together, rather than distributing them throughout the newsletter. We welcome your comments on this experiment. If you wish to share these comments, you should submit them as Letters to the Editor (which are few and far between much to the disappointment of the Editor).

ISMA Mexico City

An International Symposium on Musical Acoustics will be held in Mexico City, December 9-13, following the Cancun meeting. Technical sessions will be held at the National School of Music in the borough of Coyoacán, an old quarter of Mexico City. The theme of this symposium is "Musical Acoustics and an Interactive Musical Instruments Museum." Details of the symposium can be found at <www.unam.mx/enmusica/ismamexico.html>.

Public policy and the ASA

by E. J. Walsh

Although there is still debate over whether scientific societies should participate in the formation of public policy, a consensus has emerged that scientific zeitgeist does not exist in isolation from the culture at large. In that spirit, ASA created a Panel on Public Policy (POPP) and charged it with the responsibility to address matters of public concern within the sphere of the Society's expertise.

POPP met for the first time at the ASA meeting in Pittsburgh where a set of rules was tentatively adopted. Two noteworthy issues were also identified: implementation of the new standard on classroom acoustics and the influence of underwater noise on marine mammals. However, many other issues of interest within the Society are equally important. One of the first tasks of POPP is the compilation of a comprehensive registry of issues that the Society can, and should, address. It is this effort that each member of the Society can make an immediate contribution. If ASA members would take a moment to think about public policy issues in their professional areas and share them with POPP, the Panel will be able to more effectively represent the interests of the membership.

continued from page 1

speaker identity (voice quality), whereas the eigen-shapes are used primarily to code the speech.

That begs the next question. What does the neutral vocal tract shape depend on, and how can it be controlled by the speaker? Genetics plays a major role, as does age, culture, dialect, and vocal training. In part, we can control our own voice quality; for example, by maintaining a forward tongue position throughout our speech, by maintaining a lower larynx position (as if yawning), by maintaining our lips somewhat rounded or pursed, or by clenching our teeth. With these gestures, we "soft-wire" our neutral vocal tract shape, virtually on an instantaneous basis. Culture, dialect, and vocal training are somewhat more firm-wired, whereas the effects of genetics and age are basically hard-wired.

A recent focus has been on perception of the voice qualities *yawny*, *twangy*, and *ringing*. Rather than having human speakers produce these qualities in varying degrees (which is possible), computer simulation was used to generate sounds for listeners. The sentence length utterance /ya-ya-ya-ya-ya/ was used. It is an utterance frequently used by speakers to convey the meaning "I know, I know" or "I've heard this before." It lends itself well to computer simulation because it can have natural intonation and is all voiced (no voiceless consonants, which often don't sound natural and thus draw attention to themselves).

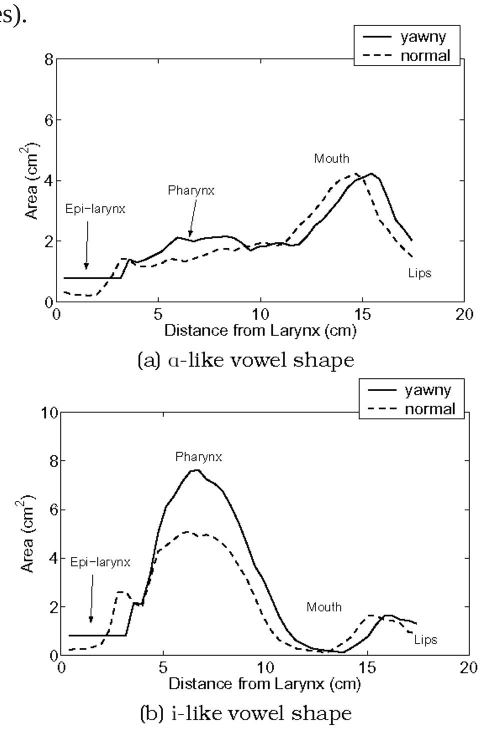

Figure 2. Modification of cross-sectional areas to transform a "normal" voice quality to "yawny."

The results were that listeners judged voices to be *yawny* when the pharynx and larynx were widened and the vocal folds were spread slightly apart during voicing. A lengthening of the vocal tract also added to the perception of yawn quality. Figure 2 shows how the cross-sectional area of the vocal tract was altered from the larynx (left) to the lips (right) in two vowels taken from the /ya-ya-…./ simulation; /*a*/-like shapes are shown on the top and and /i/-like shapes are shown on the bottom. The solid line is the "yawny" area function and the dotted line is the normal area function. Note that the pharyngeal area was enlarged for both vowels, the epilarynx tube (which is the vocal tract portion within the larynx) was widened, and the vocal tract was lengthened. For the *twang* quality (not shown in the figure), the opposite adjustments were made. The back of the vocal tract (pharynx and epilarynx tube) was narrowed, the vocal tract was shortened, and the vocal folds were adducted more. Basically, *twang* was an acoustically and aerodynamically high-impedance configuration and *yawn* was an acoustically and aerodynamically low-impedance configuration. Figure 3 shows how the listeners rated the two qualities (1 equals least preference for the quality and 10 equals greatest preference for the quality). On the abscissa are the high-impedance and low-impedance conditions described above. It is evident that the qualities were clear and distinct to the listeners.

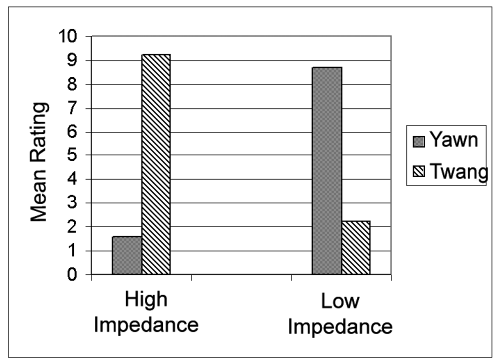

Figure 3. Listener's Rating of Yawn and Twang Qualities.

Without showing the data, we also mention the result for the third quality, *ring*. This quality is characteristic of opera singers who wish to be heard (unamplified) over long distances. Our findings were that *ring* is produced with a relatively narrow epilarynx tube and a relatively wide pharynx, a conclusion reached by Johan Sundberg many years ago. Thus, *ring* is in effect a mixture of *twang* and *yawn*. It has the benefit of a high vocal tract input impedance (like the mouthpiece of a trumpet) with a laryngeal resonance known as the singer's formant, and it also has a low first formant, giving both brilliance and warmth to the sound quality.

In conclusion, it appears that voice qualities utilized in speech and singing appear to have clearly definable vocal tract and vocal fold adjustments. Computer simulation is helpful in quantifying these adjustments and relating the qualities to each other. But many more qualities need to be studied, some of which may involve multiple sound sources (e.g., true folds, false folds, aryepiglottic folds, and perhaps air vortices shed by the larynx) and nonlinear coupling between resonators and these sound sources.

Ingo R. Titze is a University of Iowa Foundation Distinguished Professor in Speech Pathology, Biomedical Engineering, and Music. He directs the National Center for Voice and Speech. Brad H. Story is an Assistant Professor in the Department of Speech and Hearing Sciences at the University of Arizona.

First Pan-American/Iberian Meeting on Acoustics

EXHIBITOR PROGRAM

Hotel Fiesta Americana
Grand Coral Beach
Cancun, Mexico

Monday, December 2: 5:00 p.m. to 6:30 p.m.
Tuesday, December 3: 9:00 a.m. to 5:00 p.m
Wednesday, December 4: 9:00 a.m. to 1:00 p.m.

We invite all attendees of the First Pan-American/Iberian Meeting on Acoustics to participate in the ASA Exhibition by visiting the exhibits. The exhibition will include computer-based instrumentation, sound level meters, sound intensity systems, signal processing systems, devices for noise and vibration control, and acoustical materials.

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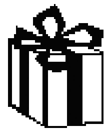

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Ultrasound Cancer Therapy

Cavitation plays a role in new ultrasound cancer therapy

by Michael Bailey

Is Chinese ultrasound therapy issuing a Sputnik-like wake-up call to the rest of the medical world? France, Germany, the US, and Japan have been researching ultrasound therapy for over 50 years. Clinical trials in the UK and throughout the West have shown that high intensity focused ultrasound (HIFU) can necrose (kill) cancer tumors, but very few HIFU cancer therapies, perhaps only prostate cancer therapy in Austria, Japan, and France, are approved and used clinically. However from 1998-2002, over 10,000 cancer patients were treated successfully in China for a myriad of cancers ranging from bone to liver, and from pancreas to skin, with machines commercially produced (and now exported) by at least three manufacturers. This somewhat sensational account of the Chinese HIFU medical advantage was the topic of an August 2002 *Seattle Times* article describing the 2nd International Symposium on Therapeutic Ultrasound (ISTU2). Our take on what can be learned from the Chinese clinical experience is: "Don't fear bubbles" [discussed with pertinent references in M. R. Bailey, V. A. Khokhlova, O. A. Sapozhnikov, S. Kargl, and L. A. Crum, "Physical mechanisms of therapeutic ultrasound," *Acoustical Physics*, January 2003 (in press)].

The core promise of ultrasound therapy is to create clinical effect within the body without damaging intervening tissue.

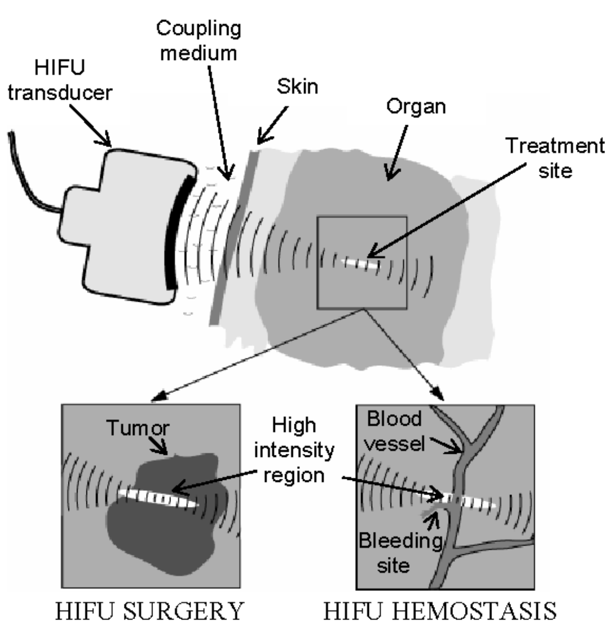

Figure 1. The HIFU beam is focused to necrose a localized tumor region or cauterize a specific bleed without injuring intervening tissue. (Courtesy of O. Sapozhnikov, Moscow State University)

Therapeutic ultrasound is a broad field encompassing physical therapy and lithotripsy (the clinical successes to date) and ultrasound gene transfection and drug delivery. In high intensity focused ultrasound (HIFU), benign ultrasonic vibrations converge through the skin to cauterize bleeds or to necrose tumors at specific sites deep inside the human body. Figure 1 shows the fundamental concept. In the focused ultrasound field, sound intensity is sufficiently low near the transducer that tissue is unharmed, but in the focal region, absorption of the intense sound waves is significant enough to thermally denature tissue proteins.

HIFU therapy started in the 1940s without image guidance. The desired effect was absorption of locally intense ultrasound and thermal necrosis of tissue. It was quickly observed that at sufficiently high amplitudes or treatment durations, mechanical damage from cavitation (bubble action) appeared. The bubbles backscattered and did not transmit the HIFU. Lesions grew wider and toward the transducer. Bubbles shielded the target from treatment. In addition, thermal diffusion from one lesion meant subsequent lesions were distorted and unpredictable. Thus, in order to necrose an entire tumor volume with a raster scan of individual lesions, intensities were restricted (on the order of 1-2000 W/cm^2), so individual lesions (~10 mm^3) formed rather slowly (1-6 s). More importantly tens of seconds of dead time were required between lesions to let the tissue equilibrate. Treatment times (over 3 hours for tumors averaging dimensions greater than 3 cm) hindered clinical acceptance. The paradigm was that absorption warmed the tissue, the temperature rose sufficiently to denature proteins, the lesion grew through thermal diffusion, and treatment ceased before the elevated absorption and heating lead to vapor bubble formation. This was the commonly accepted safe treatment method in the West. To be fair, researchers, clinicians, and manufacturers were well aware of the potential of cavitation, and in France, in particular, cavitation without heating was used to ablate tissue.

Simultaneously, advances were made in lesion imaging that permitted treatment monitoring. As yet these have not been engineered for readily available real-time monitoring. But it was observed that HIFU treatment could be monitored with standard B-mode ultrasound, when bubbles were created. Bubbles, and therefore the localized therapy site, appeared, hyperechoic (bright) on the image. The downside was that the bubbles dissolved or dispersed in less than one minute, so the technique was not useful to access the full volume treated by many successive lesions.

The change made by Chinese clinicians is to treat at high intensity (>10000 W/cm^2) so the lesion and bubbles form quickly, linearly scan the transducer so that the lesion has little time to distort, and monitor with B-mode ultrasound the rapid treatment to react to missed treatment areas. The method greatly accelerates treatment. Others had mechanically or electronically steered the HIFU focus to enlarge the lesion or let the lesion grow from the focus back to the transducer to cauterize the full thickness of an organ, but painting a stripe of lesion rather than laying individual lesions was new for cancer treatment. This treatment regime is nonlinear

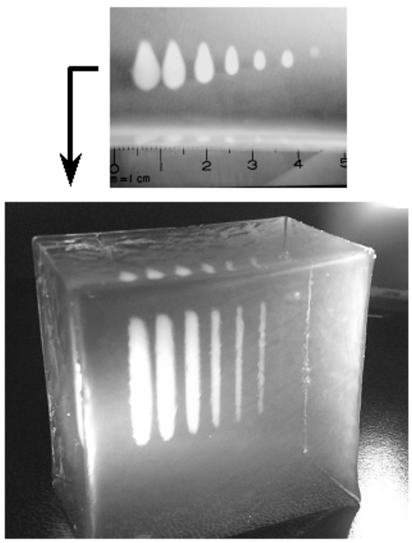

Figure 2. Top and side view of lesion stripes made by linearly scanning the transducer. The time average intensity is constant. But duty cycle decreases, pressure increases, and the lesion increases from right to left due to nonlinear acoustics and cavitation. (Courtesy of V. Khokhlova, Moscow State University)

as shown in Fig. 2. Lesion stripes are shown in a transparent tissue phantom. All stripes were made at the same time-averaged acoustic intensity. The duty cycle ("on" time divided by "off" time) is decreasing and the peak pressure amplitude is increasing from right to left. Increased production of higher harmonics by finite-amplitude acoustic propagation and increased inertial cavitation due to higher pressures lead to more efficient lesion production and larger lesions.

Evidence, in addition to Chinese clinical success, presents a number of reasons for working at high amplitude: faster treatment, increased heating efficiency, and imaging usefulness of bubbles. In fact, in many treatment regimes, bubbles appear unavoidable and may dominate the therapy. Cavitation has been detected at fairly low HIFU amplitudes by harmonic re-radiation *in vivo*. Significant heating was measured after cavitation bubbles appeared. Hyperecho, attributed to bubbles, in some cases always accompanies therapy and precedes appearance of a lesion. In addition HIFU is inherently of finite amplitude. Numerical simulations show a distortion of waveforms and amplified heating. Harmonics are easily detected with tissue harmonic imaging at diagnostic pressure levels. It appears mechanical effects or super-heating in a super-focused region, due to finite-amplitude propagation of the acoustic wave, yields bubbles. Re-radiation from the bubbles is the dominant mechanism of tissue heating, and the lesion forms after the bubbles. Throughout, linear absorption and nonlinear effects together heat tissue.

Lastly, bubbles create beneficial mechanical effects. In hemostasis, cavitation's mechanical effects emulsify blood and tissue into paste. Radiation force on bubbles can slow the bleed and drive the paste into the vessel. HIFU heat then cauterizes the paste in place. The coagulation cascade can be exited by HIFU when cavitation is present. In tumor treatment, the mechanical effects of cavitation alone without absorptive heating can destroy tumor tissue. More recent reports contradict early reports that mechanical effects increase metastasis. In fact, there is clear documentation of increased immunity to cancer following treatment. Russian researchers found 50 years ago that ultrasound at intensities too low to create thermal lesions (200 W/cm^2, small duty cycle) dissolved Brown-Pearce and melanoma tumors and prevented tumor re-growth. Today, Chinese clinicians see a similar shrinkage of tumors not treated directly by HIFU but present elsewhere in the body. It has been proposed that this noninvasive immunotherapy is due to sending fragmented antigens into the blood stream that then train the immune system to recognize and attack cancer cells.

In conclusion, at the risk of working with a somewhat stochastic mechanism (relying on random bubble nuclei), bubbles appear to be an integral part of HIFU therapy today. This conclusion should not perhaps have been a surprise since in lithotripsy, the shining success story of therapeutic ultrasound, cavitation is unavoidable and is generally recognized as a major mechanism in kidney stone comminution. Lithotripters have been designed specifically to control cavitation for therapeutic effect. Similarly, efforts are underway to manipulate HIFU waveforms to control cavitation. Chinese clinical success and the worldwide clinical experience presented at ISTU2 endorse the potential of HIFU and the potential of cavitation as a mechanism of action in cancer therapy.

Michael Bailey is a research engineer at the Center for Industrial and Medical Ultrasound in the Applied Physics Laboratory at the University of Washington. His research interests include cavitation, therapeutic ultrasound, and ultrasound imaging.

Scanning the Journals

by Thomas D. Rossing

• A special INSIGHT section on Neurobiological Systems in the 16 May issue of *Nature* includes two articles of interest to *ECHOES* readers. The first deals with instructed learning in the **auditory localization** pathway of the barn owl. Our ability to localize the source of a sound relies on complex neural computations that translate auditory localization cues into representations of space. The dominant localization cues are the relative timing and the level of the sound at both ears. In barn owls, the visual system is important in teaching the auditory system how to translate cues. Adaptive adjustment of sound localization has been demonstrated by subjecting owls to a variety of sensory manipulations and measuring the effects of these on the accuracy of auditory orienting behavior. For example, when one ear is plugged, owls initially mislocalize sounds towards the side of the open ear, but after many weeks of experience with an earplug they recover accurate orienting responses. When the earplug is removed, the owls initially make orienting errors in the opposite direction but these errors, too, disappear with experience.

Another review article in this INSIGHT section deals with **what songbirds teach us about learning**. The way in which songbirds learn their songs has some striking parallels to human speech acquisition. With the discovery of discrete brain structures required for singing, songbirds are providing valuable insights into neural mechanisms of learning.

• **Numerical optimization of violin top plates** is the subject of a paper in *Acta Acustica/Acustica* **88,** 278 (2002). The study shows that it is possible to compensate for differences in the material parameters of violin top plates by changing the distributions of plate thickness and arch height, thus keeping the eigenfrequencies unchanged. The cellular structure of wood is modeled with a honeycomb model, and the thickness and arch height compensation is determined through a stochastic optimization method called simulated annealing.

• "Talk to the Machine" is the title of a special R&D report on **speech recognition machines** in the September issue of *IEEE Spectrum*. Although the average person probably thinks of dictating reports to a PC or dialing an automated call center for flight schedules, some of the most novel and challenging work being done now involves putting speech recognition into toys, MP3 players, car navigation systems, cellphones and palm digital assistants. The push for embedded speech recognition results from manufacturers trying to cram more functions than ever into smaller devices and finding there isn't enough room for all the buttons and displays. A voice interface avoids the frustration of delving through multiple menus. Nearly all the speech recognition engines on the market today are based on hidden Markov models, which are used to represent how phonemes and allophones are pronounced and how fast they are spoken. Introduced three decades ago, their popularity shows little sign of waning. Although a recent entry, Microsoft's speech research group (with over 100 workers in Redmond and Beijing) is now second only to IBM's.

• Hyper-focusing a sound wave with **time-reversed acoustics** has been demonstrated experimentally by research in France, according to a paper in the 16 September *Physical Review Letters*. Even when a sound wave is launched by the tiniest nanomachine, it is often difficult or impossible to focus the sound wave down to the size of the machine itself, because conventional lenses don't capture a wave at its source but many wavelengths away, in the far-field. As a result, the lens cannot focus the wave to a spot smaller than half a wavelength, a roadblock called the diffraction limit which generally dictates the smallest details one can see with an optical microscope or the smallest circuits one can carve in a computer chip using light and lenses. The French researchers have now demonstrated a new way of breaking the diffraction limit by using time-reversed acoustics, a technique that takes an incident sound wave, produces a backwards-sounding version of it, and sends the reversed version right back to the source of the original sound. In the new experiment, a loudspeaker is connected to a 1.9-mm-thick glass plate and a 500 kHz sound wave 5 seconds long bounces chaotically inside the plate, the boundaries acting as small lenses for the wave.

• Undersea listening devices are helping physicists look for ultrahigh-energy **neutrinos**, according to a note in the 4 October issue of *Science*. A decade ago, these undetectable particles, moving so fast they carry as much energy as a pitched ball, were a theoretical possibility but nothing more. Now physicists are firmly convinced that Earth is constantly being bombarded by ultrahigh-energy neutrinos, which are part of the debris generated when extremely energetic cosmic rays slam into the atmosphere, water, or rock, creating showers of particles. Using data from submarine-listening facilities, several projects are paving the way for higher profile efforts soon to come. To make an audible click in the ocean, a neutrino must carry a huge amount of energy, perhaps 10^{16} electron volts. Physicists from Stanford University are calibrating instruments belonging to the Atlantic Undersea Test and Evaluation Center (AUTEC), for example, to determine whether they are capable of picking up the sounds of passing neutrinos.

• A paper in *Acoustical Physics* **48**, 430 (2002), translated from *Akusticheskii Zhurnal*, deals with **calculation of the nonlinearity parameter for gaseous and liquid mixtures**. Relations for estimating the derivatives of the speed of sound with respect to temperature and pressure in two-component mixtures are obtained.

• Inhibition in the brain plays a key role in **sound localization**, according to an article in the Search and Discovery section of the October issue of *Physics Today*. Scientists at the Max Planck Institute of Neurobiology and University College, London have shown that the neuronal response to interaural time differences (ITDs) in Mongolian gerbils is determined by fast inhibitory inputs within the brain. Neurons in the medial superior olive (MSO) in the brain receive inputs from both cochleas via the auditory nerves. But MSO neurons also receive inputs from two other processing centers, the medial and lateral nuclei of the trapezoidal body and these appear to be inhibitory. To examine the role of inhibitory inputs, the researchers measured neuron firing rates following the injection of strychnine, which blocks the glycine receptors and effectively turns off the inhibition and shifts the peak in the ITD response toward zero.

- The May/June issue of *Acta Acustica/Acustica* is a special issue devoted to **Psychoacoustics, physiology and models of the central auditory system**. The issue includes review articles by D. Hammershøi and H. Møller on Methods for Binaural Recording and Reproduction; A.R. Palmer and T.M. Shackleton on The Physiological Basis of the Binaural Masking Level Difference; and B.C.J. Moore and H. Gockel on Factors Influencing Sequential Stream Segregation as well as 10 scientific papers. The special issue was edited by Birger Kollmeier.
- A paper entitled "Sound level meter standards for the 21st Century" in the August issue of *Acoustics Australia* reports on a **new sound level meter standard** (IEC61672-1:2002). This paper, based on the 2001 President's Prize paper awarded at the Australian Acoustical Society Conference, reminds us that most modern sound level meters rely on digital rather than analog circuitry.
- The shape of a cracking whip is the subject of a paper in the 17 June issue of *Physical Review Letters*. The crack of a whip is produced by a shock wave created by the supersonic motion of the tip of the whip in air (see Acoustics in the News in *ECHOES* **12** (3), p.8). A dynamical model for the propagation and acceleration of waves in the motion of whips is presented in this paper. The contributions of tension, tapering, and boundary conditions in the acceleration of an initial impulse are studied theoretically and numerically.
- A **new kind of ocean wave** has been detected at the Hawaii-2 Observatory, according to a paper in *Geophysical Research Letters* **29**, 57 (2002). Propagating at the speed of sound in water, the new wave, which appears to be a coupled acoustic and Rayleigh wave, induces motion of the sea-floor sediments and creates regions of expansion and compression in the water. The new wave requires that the Rayleigh wavelength be shorter than the water's depth and that the shear velocity at the interface not exceed the sound velocity in water.
- An ultra-sparse code underlies the **generation of neutral sequences in a songbird**, according to a letter in the 5 September issue of *Nature*. Sequences of motor activity are encoded in many vertebrate brains by complex spatio-temporal patterns of neural activity; however, the neural circuit mechanisms underlying the generation of these pre-motor patterns are poorly understood. In songbirds, one prominent site of pre-motor activity is the fore-brain robust nucleus of the archistriatum which generates sequences of spike bursts during song and recapitulates these sequences during sleep.
- About a third of the planned $250 million International Monitoring System (IMS), which includes **detectors for infrasound and hydroacoustic waves**, is up and running, although the data are being fed only to government-run centers in a few dozen nations that have signed the Comprehensive Nuclear Test Ban Treaty of 1996, according to a note in the 5 July issue of *Nature*. So far, the United States has opposed ratification of the Treaty, leaving it somewhat in limbo. The IMS is expected to be fully working by 2007.

Acoustics in the News

- Tonight the Concert Hall Takes Center Stage, which appeared in the 2 October issue of the *Wall Street Journal*, describes the variable acoustics of a new concert hall at the University of California in Davis. Acoustical design of the concert hall, part of the Mondavi Center for the Performing Arts, was done by Ronald McKay and his colleagues at McKay Conant Brook. "His influence represents a recent phenomenon and new-found respect for acoustical consultants at a time when shrinking budgets and the growing popularity of lighter, less expensive building materials has complicated the creation of quality performing arts centers," the story reads. The multi-purpose hall includes a 25-ton movable orchestra shell as well as oversize air ducts.
- A Spanish engineer has marketed a gadget called Why Cry that will analyze the sound of a baby's cry and tell parents whether their baby is hungry, bored, tired, stressed or uncomfortable, according to a story from Reuters in Madrid on October 8. The inventor plans to donate a share of any profits to a charity for babies.
- Scientists at Glasgow University (Scotland) have developed a computer mouse that vibrates when it encounters a line on a graph and a soundscape that interprets graphs for blind people, according to a story from Reuters in Leicester, England on September 9. Lines on a graph are represented by tones that vary in pitch according to whether the line is rising or falling. Several such tones could be used to represent different lines of the same graph.
- The Navy won approval to deploy two ships that use controversial low-frequency sonar to detect faraway submarines, according to a story in the July 16 *Washington Post*. The ruling by the National Oceanic and Atmospheric Administration (NOAA) grants the Navy an exemption from federal rules that guard marine mammals from incidental injury. The agency concluded that protective measures required of the Navy will ensure the effects of the sonar will be negligible and will not undermine the long-term health of whales and other ocean mammals. Under the NOAA permit, the Navy will use visual sighting and the kind of passive sonar used by commercial fishing fleets to make sure no marine mammals are within the prohibited zone around the noise blast. The sonar would also not be allowed within 12 nautical miles of coastlines.
- Not only are bubbles behind the dominant sounds above and beneath the sea, they also influence global climate, storm systems and the exchange of gasses and biological matter, according to a story in the Aug. 22 *ABC News online*. Bubbles influence the environment mostly as they form and break. As ocean waves crest and topple, air and sea water mix to form whitecaps. Inside each whitecap is a rich swirl of bubbles called the bubble plume. As the bubbles form, they pocket gasses and transfer them between the air and sea. As they rise up through the water column, they scrub out and collect organic material and bacteria which are released when the bubbles burst. Navy researchers have long studied the different sounds bubbles make, since they use acoustical instruments when looking for submarines. Recognizing what sounds are bubbles can help engineers tune out the background noise of bubbles. Climate researchers, meanwhile, can tune in to the noise of bubbles to estimate the flow of gas between air and sea.
- Music Plus One, software developed by mathematician Christopher Raphael that makes it possible for computers to play music artistically with a human performer, was the subject of a story in the October 4 issue of *ABC News online*. Some attendees at the Pittsburgh ASA meeting heard Raphael, an oboist as well as a mathematics professor at the University of Massachusetts, demonstrate his software in session 2aMU5. Those who did not can hear samples on his Web site: http://fafner.math.umass.edu/~raphael/music_plus_one/mpo.html.

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