Vanderbilt Bill Wilkerson Center for Otolaryngology and Communication Sciences

Department of Hearing & Speech Sciences

Research Report
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Vanderbilt University Medical Center

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INTRODUCTION

The Department of Hearing and Speech Sciences and the Vanderbilt Bill Wilkerson Center are dedicated to improving the lives of the communicatively handicapped through service, education, and research. In addition to recording more than 50,000 patient visits annually in all areas of communication disorders, the Department offers the Master's degree in speech-language pathology and Doctor of Philosophy degrees with emphasis in either speech-language pathology or audiology. The Master of Deaf Education (MDE) degree and the Doctor of Audiology (Au.D.) degree are offered through Vanderbilt University School of Medicine. The graduate program includes academic, clinical, and research activities.

The research program, housed primarily on the 10th floor of our new building, encompasses a wide variety of topics in the areas of hearing science, language, speech production and perception, animal models, and human performance. Within each of these areas, work focuses on both applied and basic issues.

The following is our 18th research report (our 1st report was published in 1982), which lists our personnel, describes our facilities, and provides abstracts of our most recent scientific work. Requests for further information may be directed to the individual authors at the address given below. E-mail questions and comments may be directed to d.wesley.grantham@vanderbilt.edu. For additional information regarding the Vanderbilt Bill Wilkerson Center for Otolaryngology and Communication Sciences or Vanderbilt Department of Hearing and Speech Sciences, their programs, staff, and mission, please visit our home page on the world wide web:

http://www.mc.vanderbilt.edu/root/vumc.php?site=aboutbw

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FACILITIES AND EQUIPMENT

The Department of Hearing and Speech Sciences comprises one part of the Vanderbilt Bill Wilkerson Center for Otolaryngology and Communication Sciences, which is housed within five floors of a new 10-story building on the campus of the Vanderbilt University Medical Center. The entire 10th floor of this state-of-the-art facility is dedicated to research and houses some 20 separate laboratories that conduct both clinical and basic investigations in the areas of hearing, speech, and language science. Emphasis is on both behavioral and electrophysiological measurements associated with communication science and communication disorders. The many ongoing research projects are tied closely to our academic program (located on the 8th floor) and to the speech, language, and audiology clinics that serve the Middle Tennessee region (located on the 6th and 9th floors). Research activity is also coordinated with the Department of Otolaryngology and the Vanderbilt Voice and Balance Disorders clinics (located on the 7th floor). In addition, animal research facilities associated with communication science are located in other buildings on the Vanderbilt University Medical Center campus. Following are descriptions of the various research laboratories of the Bill Wilkerson Center.

The **Anechoic Chamber Laboratory (ACL)** is a stand-alone computer-controlled laboratory that allows efficient control of virtually any kind of psychoacoustic experimentation in free sound-field situations. The chamber (internal dimensions 4.6m x 6.4m x 6.7m) is covered on all six surfaces by fiberglass wedges and has a measured low-frequency cutoff of 100 Hz. This laboratory is controlled by three computer systems interfaced to Tucker-Davis System 2 and System 3 signal acquisition and processing devices. In the chamber itself, there is a full circular horizontal array of 64 loudspeakers with a radius of 2 m and spanning 360°. These loudspeakers will be employed in a variety of experiments concerned with localization, the precedence effect, and simulated motion perception.

The **Reverberation Chamber Laboratory (RCL)** is a stand-alone computer-controlled laboratory that allows efficient control and simulation of a large number of sound-field environments. This laboratory is controlled by a PC computer system interfaced to Tucker Davis Technologies (TDT) RX8 multi-I/O signal acquisition and processing device. A Crown 8-channel amplifier, GSI Audiometer, multi-channel sound card and up to 16 configurable loudspeakers are also dedicated to reverberation chamber use. The chamber itself is a random-incidence hard-walled design which is capable of producing an essentially diffuse sound field. The chamber also includes a removable blanket system which allows for systematic variation in average reverberation time from approximately 2.7 seconds to less than 0.3 seconds. The flexibility of the reverberation chamber in terms of reverberation characteristics and loudspeaker configurations have made it an ideal resource for experiments concerned with speech recognition performance, both with and without amplification, across a variety of environments of interest.

The **Dan Maddox Hearing Aid Research Laboratory (DMHARL)** is under the direction of Dr. Todd Ricketts and is devoted to the evaluation and refinement of existing amplification and

cochlear implant technology; the examination of basic differences in the hearing of those with normal and impaired thresholds; the development and refinement of fitting and counseling techniques; and, the evaluation and design of signal processing schemes for hearing aids and cochlear implants. The laboratory is equipped with a control room and two custom sound-attenuating test rooms where normal-hearing and hearing-impaired subjects are tested individually under headphones or via loudspeakers. The laboratory is controlled by four PCs and contains typical audiometric equipment such as two audiometers with high frequency testing capability, Otoscope, GSI TympStar Middle ear Analyzer, CD players, two 12-channel amplifiers, and the necessary hardware and software to program a variety of programmable hearing instruments including four different probe microphone systems. Additional hardware includes a two-channel spectrum analyzer, a System3 array processor from Tucker-Davis Technologies (TDT), two mutli-channel sound cards and multiple loudspeakers allowing for a great number of sound presentation configurations. The TDT processor is linked via high-speed fiber-optics to an array of external signal processing modules providing digital recording, processing, and playback of signals.

The **Psychophysiology Research Laboratory** is under the direction of Dr. Alexandra Key and focuses on EEG/ERP studies of speech/language processing and cognitive functioning in infants, children, and adults. This laboratory includes a sound-attenuated participant testing room and an adjacent control/observation room which houses equipment. The EEG equipment includes two 128-channel EEG systems (Electrical Geodesics, Inc) that also capable of functioning as a singe 256-channel system (for studies focused on brain source analysis). Each system includes a Macintosh G5 computer for data collection and a Dell PC with E-prime software for experiment design and stimulus presentation (auditory and visual). EEG data are recorded with high-density geodesic sensor nets connected to super high impedance amplifiers that allow for good quality data without skin abrasion. The participant room is equipped with two video cameras for observing and recording participant behavior. Auditory stimuli can be delivered via a single ceiling-mounted speaker (mono) or two speakers (stereo) on each side of the participant. Audio-visual equipment allows to present participant with VHS, DVD, PC video/sound and to record test sessions on VHS or DVDs.

The **Auditory Physiology Laboratory (APL)** is directed by Dr. Linda J. Hood and focuses on physiology of the auditory system at cochlear, subcortical and cortical levels. Studies encompass several perspectives including normal and disordered auditory systems and hearing loss related to genetic mutations. Recent areas of research have focused on efferent system function in normal, developing and aging human auditory systems, and neural responses from the eighth nerve through the cortex in infants, children and adults. Research related to hereditary hearing loss involves characterization of auditory function in carriers of genetic mutations associated with recessively inherited deafness in order to understand the specific phenotypic characteristics of certain genotypes. Another area of research involves auditory neuropathy/dys-synchrony where research focuses on understanding the underlying mechanisms and functional characteristics in order to improve management and communication skills of these patients. The Auditory Physiology Laboratory consists of a two-room suite with a double-walled sound-treated room and adjacent control room and a second research area for data analysis and management.

Laboratory equipment includes multiple Macintosh and PC based systems that drive hardware for transient, distortion product, and stimulus frequency otoacoustic emissions studies and specialized equipment for studying characteristics of the medial olivocochlear system through suppression of otoacoustic emissions. Additional laboratory otoacoustic emissions systems are directed towards study of cochlear fine structure and separation of response components. Two state-of-the-art auditory evoked potential systems are used for recording auditory brainstem, auditory steady state, and cortical responses along with capacity for novel stimuli and recording method development. These specialized laboratory systems are supported by comprehensive signal generation, analysis and calibration systems and equipment necessary for baseline auditory testing.

The **Psychoacoustics Laboratory (PAL)** is under the direction of Dr. Wesley Grantham and is devoted to psychoacoustic experimentation, especially in areas concerned with binaural hearing. This laboratory is equipped with a control room and a double-walled sound-attenuating test room in which as many as three subjects can be tested simultaneously under headphones. The laboratory is controlled by two PC computer systems, interfaced to a wide array of signal generation and acquisition equipment from Tucker-Davis Technologies (System 2 and System 3). Other equipment includes the necessary measuring and calibrating instruments as well as a full complement of analog signal generation and control devices.

The **Auditory Development Laboratory (ADL)** is directed by Drs. Anne Marie Tharpe and Daniel Ashmead. Their work has merged Tharpe's expertise in pediatric audiology with Ashmead's background in developmental psychology, resulting in a multidisciplinary emphasis on the impact of hearing loss on infants and young children. The three-room laboratory suite is composed of two custom sound-attenuating booths (8x7 ft and 12x13 ft) with one shared control room for pediatric auditory assessments. The laboratory houses typical audiometric equipment for pediatric assessment including an audiometer with sound field and visual reinforcement capability, auditory brainstem response equipment, otoacoustic emission, and immittance equipment. In addition, probe microphone technology is available for in-situ testing of hearing technology. Two computer workstations support the lab with inferential statistical analysis software used for various studies of audition. Both sound booths are equipped with audiovisual recording units that are used for frame-by-frame data analysis of audiovideo recordings. The lab is also equipped with a Tucker-Davis acoustics hardware/software system for control of specialized experimental protocols such as sound localization and interaural processing.

The two **Speech Science Laboratories (SSL 1 and SSL 2)** are under the direction of Dr. Ralph Ohde. SSL 1 is devoted primarily to speech perception and speech acoustics research. This laboratory consists of a control room and a double-walled sound-attenuating test room that can test up to three subjects simultaneously under headphones. SSL 1 is controlled by a pentium-based PC system and a 486 PC system, which are used in the generation and acoustic analysis of stimuli, and for the control of experimental paradigms. Acoustic analysis is performed using either KayPENTAX Multi-Speech (Model 3700) or the CSpeech software package (Milenkovic, 1996). Synthetic speech is generated using either the Klatt cascade/parallel formant synthesizer

(Klatt, 1980; Klatt and Klatt, 1990) or the KayPENTAX Analysis-Synthesis Laboratory (Model 5104). SSL 1 is also equipped with an audio-video recording system for the generation of high quality tape recordings. This laboratory includes equipment necessary for measuring and calibrating instruments, for analog signal generation, and for control of devices. The emphasis of the work in SSL 2 is on the phonetic and acoustic analysis of speech sounds. This laboratory contains two workstations for the phonetic analysis of speech. Each of these stations has a phonetic transcriber used in the phonetic transcription of normal and disordered speech. In addition, SSL 2 has two workstations for the acoustic analysis of speech that is performed using KayPENTAX software for the Computerized Speech Lab (CSL - Model 4500), and pentium-based PC systems supporting CSL.

The **Developmental Stuttering Project (DSP)** laboratory , under the direction of Dr. Edward G. Conture, investigates stuttering in pre-school aged children. The DSP consists of a federally-funded research program of over 30 years standing that empirically studies linguistic and emotional contributions to childhood stuttering. These contributions are assessed by acoustic, behavioral, standardized test and psycho-physiological means. The DSP utilizes three rooms for data acquisition, one room for data analysis, and one interview room. Each of the three data acquisition rooms is equipped with two adjustable, wall-mounted high-resolution cameras and table microphones, instrumentation used for acquiring audio-video signals during standardized testing and examiner-child conversational speech samples. One of these testing rooms also houses a computer-based data collection system for the acquisition and measurement of behavioral and physiological measures. This system consists of the Biopac MP150 system for the acquisition of heart rate/variability (ECG), skin conductance (GSR), and respiratory signals as well as the Noldus Observer for the synchronization and subsequent assessment of interactions of multiple data streams. The data analysis room consists of four computer workstations used for a variety of data analyses. Each workstation includes Systematic Analysis of Language Transcripts (SALT) for transcription of conversational speech, coding of stuttering and other types of disfluency, and extraction of linguistic measures. These workstations also provide assess to a statistical package for data analysis (SPSS) and behavioral coding software (Pro-Coder). Furthermore, one computer provides access to Computerized Speech Lab (CSL), a system used to for the acoustic analysis of correlates of speech, and another computer coordinates audio and video inputs among the various testing rooms for digital and analog recording.

The **Child Language and Literacy Laboratory (CLL),** devoted to the study of typical and atypical language and literacy acquisition is under the direction of Dr. Melanie Schuele. The CLL lab and the Child Language Intervention Programs (Dr. Stephen Camarata) share lab space, including six research/treatment rooms and a Language Analysis Laboratory. All research/treatment rooms are outfitted with child-sized furniture providing a comfortable atmosphere for interaction between parents, children, and researchers. Three research/treatment rooms are equipped with two wall-mounted high-quality video cameras which connect to a server for video-recording with split screen recording possible. These three rooms are accessible for observation through a two-way mirror. The Language Analysis Laboratory includes five workstations. These workstations allow for transcription and analysis of audio and video

recordings of child speech/language, parent-child interactions, and examiner-child interactions. Workstations are equipped with Microsoft Office (Word, Excel, PowerPoint, Publisher, Excel, Access), SPSS for statistical analysis, and Systematic Analysis for Language Transcripts (SALT) and Computerized Profiling (CP). In addition, one workstation includes Computerized Speech Lab (CSL) software.

The **Multisensory Research Laboratories (MRL)**, under the direction of Dr. Mark Wallace, are state-of-the-art facilities for examining the processes by which other sensory systems (e.g., vision, touch) can influence auditory behaviors and perceptions, as well as the neural mechanisms that underlie these interactions. The MRL is comprised of three laboratories for performing in vivo electrophysiological analyses, each designed to accomplish the objectives of a particular research theme. The first lab is structured to examine the development of and plasticity in cross-modal sensory representations, with emphases on how auditory-nonauditory interactions mature, and how these interactions are shaped by sensory experience. The second lab seeks to better elucidate the nature of multisensory interactions in the cerebral cortex, with the ultimate goal of understanding how visual and tactile stimuli can alter higher-order auditory perceptions, such as speech. The third lab is designed to reveal how auditory stimuli can direct certain behaviors, such as locating an object in space, and how these processes can be impacted by other sensory stimuli. Each of these labs in outfitted with a host of sophisticated equipment for recording unit activity from various regions of the brain, for the delivery a complex array of different sensory stimuli, and for the acquisition and analysis of unit data from the brain.

In addition, two research suites are dedicated to examining similar issues in human subjects. These labs are structured to examine human psychophysical performance in response to auditory and non-auditory cues. Two examples of ongoing studies are an examination of the effects of visual cues on the perceived location of an auditory target, and an examination of how the timing of auditory cues can alter the perceived time of the occurrence of visual events. Each of these labs work in conjunction with collaborations to examine the brain networks activated during the performance of these tasks, as examined using neuroimaging techniques such as event related potentials (ERPs) and functional magnetic resonance imaging (fMRI). Experiments are performed on both normal and various clinical populations (e.g., dyslexics, aged populations, hearing-impaired, visually-impaired).

The ultimate goal of the MRL research program is to further our understanding of how the brain integrates information from the different senses, and to apply this knowledge to improve the quality of life of those suffering from a variety of sensory processing deficits. Two examples of the potential application of this knowledge base lay in the realms of dyslexia and hearing-impairment. Recently, our lab has proposed that developmental dyslexia, a prevalent and costly reading disorder, may be linked to a specific dysfunction in cross-modal processing. With this framework, we have identified a network of affected brain areas, and have proposed a remediation strategy based on this database. In the realm of hearing impairment, it has been well established that concurrent visual cues (i.e., lip-reading) can greatly improve the intelligibility of heard speech. However, little was known about the underlying neural mechanisms for such improvements, a gap that our research program is working hard to fill, and which will hopefully yield better strategies (and devices) to further improve the quality of the spoken signal.

The **Auditory Neuroplasticity Laboratory (ANL),** under the direction of Dr. Daniel Polley, is dedicated to the study of the mechanisms and therapeutic potential of brain plasticity. The ANL is composed of three research suites in Medical Research Building 3. These facilities offer seven sound attenuating booths in which researchers can manipulate animals' experience with sound and then test the effects of this experience with state-of-the-art single cell neurophysiological recording equipment and behavioral testing equipment. Neurophysiological recordings are made under stereotaxic guidance with conventional metal microelectrodes or multi-site silicon probes using Tucker-Davis (System 3) hardware. Similar equipment is used to make recordings of the auditory brainstem response with low-impedance subdermal electrodes. Custom-made behavioral testing apparatuses permit measurement of the acoustic startle reflex, pre-pulse inhibition and active avoidance in rodents as a means to assay auditory detection and discrimination thresholds. These devices are supported by multiple PC workstations used to generate and measure acoustic stimuli as well as analyze their relationship to neurophysiological processing.

The **Auditory Neurophysiology Laboratory** is located in the Vanderbilt University Department of Psychology. This facility is equipped to conduct anatomical and neurophysiological studies of the brain in research animals. Two research rooms contain contains double-wall IAC sound chambers, TDT stimulus generation and Plexon multichannel recording equipment. Shared laboratory space contains microscopes for anatomical studies, a histology laboratory for tissue processing, and walk-in cold room for tissue storage.

The **Computer Laboratory** (housed on the 8th floor) is devoted to computer teaching for students and in-service training for staff and faculty members. This laboratory is equipped with state-of-the-art computer equipment: a Local Area Network (LAN) connecting 12 computers in a classroom setting, plus a "podium" PC with direct connection to the room PC projector. All computers have hardwire internet connection. This classroom, like the other classrooms on this floor, is also equipped with a document projector and a closed-circuit camera system for FULL audio-visual capability.

The Vanderbilt Balance and Hearing Center is located on the 7th floor of the Bill Wilkerson Center. The Balance and Hearing Center, a division of the Department of Hearing and Speech Sciences, is equipped with state-of-the art equipment for comprehensive assessment of vestibular and auditory disorders. The facility includes a sound treated room, a diagnostic audiometer, a tape recorder and compact disk player for speech audiometry, a microprocessor immittance meter, three otoacoustic emissions devices, a rotary vestibular test chair, a computerized electronystagmography system, a computerized dynamic posturography system, an evoked response system with capability for 64 channels simultaneous brain signal acquisition, a 4-channel clinical evoked potentials system, and, two computerized hearing aid analysis systems. Additionally the facility contains 6 personal computers for use by students and the four staff audiologists, and a neurotologic examination room. The facility also includes student office space. Students also conduct research and acquire clinical practicum experiences at the 1000 square foot audiology facility located within The Vanderbilt Clinic on the Vanderbilt University

Medical Center campus. This facility is equipped with three sound treated rooms for adult and pediatric hearing assessment, three diagnostic audiometers, two immittance meters, one evoked response system, and one electronystagmography system.

The Voice Center of Vanderbilt University Medical Center is adjacent to the Vanderbilt Balance and Hearing Center on the 7th floor of the Bill Wilkerson Center. The Center includes four state-of-the-art laryngological examination rooms, a specially-equipped room for the treatment of Spasmodic Dysphonia and facial paralysis, a voice testing laboratory, a digital audio tape recording facility, three videostroboscopic laryngoscopy rooms, specially designed areas for patient consultation and education, and several sound-attenuated, humidity-controlled rooms with complete audio and video capabilities. The Center houses a team of physicians, speech pathologists, and singing voice specialists who are trained in the diagnosis and treatment of disorders of the larynx and problems affecting the voice.

ACKNOWLEDGMENTS

Virtually all of the equipment and most of the facilities described above were nonexistent prior to 1979. We are proud of the manner in which our research program has developed over the past thirty years. Many agencies and benefactors deserve recognition for their significant contribution to the development of our facilities. We gratefully acknowledge the contributions of the following agencies, corporations, and foundations for their financial assistance:

American Speech-Language-Hearing Foundation (CCL)
Argosy Electronics, Inc.
Bernafon AG
Cochlear Americas (ACL, RCL)
Digital Equipment Corporation (SSL 1)
Dan Maddox Foundation (Dan Maddox HARL)
Defense Advanced Research Projects Agency (DOD/DARPA)
EAR Foundation
Etymotic Research
Intelligent Hearing Systems (APL)
Life and Casualty (SSL 1, SSL 2)
Maternal Child and Health Services (ACL)
Malcolm Fraser Foundation
MED-EL Corporation (ACL, PAL)
Medtronic, Inc. (DO)
NIH (NIDCD) (ACL, PAL, SSL 1, DO, CCL, APL)
NIH (NINDS) (MRL)
NIH (NICHD) (MRL)
National Easter Seal Society
National Life and Trust (SSL 2)
National Organization of Hearing Research (ACL)
National Science Foundation (PAL, ACL)
Nissan Motor Corporation (SSL 1)
Northern Telecom, Inc. (SSL 1)
Office of Navy Research (DO)
Phonak, Inc. (ADL, Dan Maddox HARL)
Potter Foundation (SSL 1)
Sharplan Lasers, Inc. (DO)
Siemens Hearing Instruments
Starkey Laboratories Incorporated
Robert Wood Johnson Foundation (CLL)
South Central Bell (SSL 1)
Spencer Foundation (ACL, SSL 1, CLL)
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Veterans Administration-Medical and Surgical Merit Review Research
Veterans Administration-Rehabilitation Engineering (PAL)
Veterans Administration-Rehabilitation Research and Development Service
Veterans Administration-Vanderbilt Hearing Aid Study

THE NATIONAL CENTER FOR CHILDHOOD DEAFNESS AND FAMILY COMMUNICATION

In 2005, the Vanderbilt Bill Wilkerson Center opened the National Center for Childhood Deafness and Family Communication (NCCDFC). The NCCDFC seeks to improve outcomes for children with hearing loss and their families through a triad of exemplary service, education, and research. This influence extends beyond the walls of the NCCDFC through our commitment to public and professional education and advocacy nationwide. The specific goals of the Center are to 1) achieve excellence in service provision to infants and young children with hearing loss and their families, 2) enhance knowledge and awareness of the nature and impact of auditory disorders from a multidisciplinary perspective, 3) shape the future of children with hearing loss through national and international leadership, 4) provide innovative training approaches and materials for both pre-service and post-service professionals who work with infants and toddlers with hearing loss, and 5) promote public awareness in the prevention of hearing loss in children.

The NCCDFC Service Division strives to provide best practice, proven service delivery in the areas of early childhood oral education at the Mama Lere Hearing School at Vanderbilt, speech-language pathology, and audiologic management. Through a family-centered approach, our goal is to maximize a child's hearing potential so that he or she can communicate independently and effectively in mainstream society while respecting individual differences.

The NCCDFC Research Division brings together clinicians and scientists from a range of disciplines, areas of expertise, and research interests – all with a focus on the pediatric population. The research program is composed of basic science and translational research projects designed to improve understanding of normal hearing processes and various forms of childhood deafness, and to develop new and innovative methods to improve evaluation and to address the management needs of pediatric patients and their families.

The NCCDFC Education Division initiated a Master in Education of the Deaf (MDE) degree program that accepted its first students in Fall of 2006. This one- to two-year program emphasizes the training needed to develop spoken language and auditory skills in deaf and hard-of-hearing children. This program provides a unique, interdisciplinary approach to teacher training by combining training in audiology, speech-language pathology, and deaf education. Also beginning in 2006, speech-language pathology and audiology graduate students can opt to participate in our Specialty Track in Identification and Management of Infants and Children with Hearing Loss.

THE SCOTTISH RITE MASONS RESEARCH INSTITUTE FOR COMMUNICATION DISORDERS

The Nashville Scottish Rite Foundation, Inc., the philanthropic arm of Scottish Rite Freemasonry in the Valley at Nashville, sponsors the Scottish Rite Masons Research Institute for Communication Disorders at the Vanderbilt Bill Wilkerson Center for Otolaryngology and Communication Sciences. The primary emphasis of the research institute is on improving the methodology for the treatment of speech, language and hearing disorders in children.

The joint project between the Wilkerson Center and the Nashville Scottish Rite Foundation has been fostered in large part by Illustrious Joseph Martin, 33°, Deputy of the Supreme Council for Scottish Rite Freemasonry in Tennessee. Mr. Martin has also played an active role on the Bill Wilkerson board of directors; during his six-year tenure, he served on the executive committee and as chair of the board from 1993 through 1995. Active in both organizations, Mr. Martin recognized the opportunity for a cooperative effort between the Center and the Foundation. More recently, Mr. Dan Jones has become a leader in the Scottish Rite and continues the collaborative relationship between Bill Wilkerson Center and the Scottish Rite Masons Research Institute.

Since the 1950's, the various Valleys of the Supreme Council, 33° of Scottish Rite Freemasonry have established Scottish Rite Centers nationwide for children with speech and language disorders. These Centers, which began with a pilot project in Colorado, are now found at 73 locations throughout the United States. Staffed with speech-language pathologists and other trained personnel, each Center provides diagnosis and treatment of speech and language disorders and associated learning disabilities. The project at the Wilkerson Center represents the first research effort sponsored by the Scottish Rite.

This research arm of the Scottish Rite Center is dedicated to the advancement of treatment technology for language disorders. Additionally, a service and teaching component is part of the program. Many children have the opportunity to receive therapy as a part of the applied research process. Another important function of the research program is the dissemination of information to the other Centers over the country. Continuing education courses and seminars update professional personnel on the latest research methodology.

The Nashville Scottish Rite Foundation has been a major supporter of the Wilkerson Center since 1982.

VANDERBILT UNIVERSITY T35 RESEARCH TRAINING PROGRAM: SUMMER PROGRAM FOR AUD STUDENTS FUNDED BY NIDCD

The Department of Hearing and Speech Sciences at Vanderbilt University offers short-term research traineeships each year to students in the Vanderbilt AuD program and to students from AuD programs at other universities. These traineeships are funded by the National Institute on Deafness and Other Communication Disorders (NIDCD) at the National Institutes of Health (NIH) through a program of Pre-Doctoral Ruth L. Kirschstein National Research Service Award (NRSA) Short-Term Research Training Grants (T35).

This AuD student traineeship program is part of an initiative by the NIDCD that focuses on the importance of research to the profession of audiology and the importance of exposing students to research. Students who pursue AuD degrees generally do not have opportunities to undertake directed, full-time research as a part of their AuD training program. This research traineeship program is one way that NIDCD is encouraging students with potential interest in research to explore those interests. It provides an excellent opportunity for AuD students to obtain significant exposure to research in an active laboratory conducting basic research in hearing science and/or translational research related to audiology.

Student trainees work alongside established research scientists in one of twelve hearing research laboratories at Vanderbilt and are involved in a specific research project. The program is designed to give trainees an opportunity to learn about research through concentrated, focused, full-time hands-on experience. In addition to learning first hand about the process of conducting research, students have opportunities to attend seminars and lectures, participate in discussion groups, attend meetings of investigators to discuss projects, and participate in discussions related to the ethical practice of research. Traineeships also include funds that support travel to the annual meeting of the American Auditory Society where trainees can present the work they completed during their traineeship.

Traineeships are awarded each year on a competitive basis. While it is anticipated that most traineeships will be completed during the summer months of students' programs, it also may be possible to complete a traineeship at other times during the year. Students from all AuD programs in the United States who are eligible for NIH NRSA support (e.g., U.S. citizens or permanent residents) may apply for this training program. For more information and application materials, please contact Linda Hood, PhD, Principal Investigator/Program Director (email: **linda.j.hood@vanderbilt.edu** or phone: 615-936-4612).

T35 Traineeship Preceptors and Research Areas

Daniel Ashmead, Ph.D. – Auditory and Visual Motion Perception
Fred Bess, Ph.D. – Minimal Hearing Loss
Edward Conture Ph.D. – Developmental Stuttering
D. Wesley Grantham, Ph.D. – Binaural Hearing, Cochlear Implants
Troy Hackett Ph.D. – Auditory System Neuroanatomy
Linda Hood, Ph.D. – Auditory Physiology, Auditory Neuropathy/Dys-synchrony
Ben Hornsby, Ph.D. – Speech Understanding and Amplification

Gary Jacobson, Ph.D. – Vestibular System Function
Alexandra Key, Ph.D. – Cognitive Processing, Brain Activity, Event-related Potentials
Dan Polley, Ph.D. – Cortical Development and Plasticity
Todd Ricketts, Ph.D. – Hearing Aid Research
Anne Marie Tharpe, Ph.D. – Pediatric Audiology, Auditory Development
Mark Wallace, Ph.D. – Brain Bases of Multisensory Processing

ABSTRACTS OF RESEARCH PROJECTS

A. Hearing and Vestibular Science — Applied

Gravel, J.S., Stredler-Brown, A., **Tharpe, A.M.**, and Oyler, R. (2008). Children with mild and unilateral hearing loss: Proposals for research. *Seminars in Hearing*, 29(2):212-227.

Although questions remain concerning the impact of permanent unilateral hearing loss (UHL) and mild bilateral hearing loss (MBHL) on child development, there is nonetheless evidence that at least some children experience measurable problems, particularly at school age (e.g., grade retention; need for support services). After evidence-supported oral presentations and discussions among clinical experts during the 2005 National Workshop on Mild and Unilateral Hearing Loss, a series of recommendations was developed regarding (1) early identification (hearing screening), (2) audiologic assessment, (3) hearing technologies, and (4) early intervention needs of infants and young children with UHL and MBHL.

Harry, T., McCaslin, D.L., and **Jacobson, G.P.** (In press). Bilaterally absent vestibular evoked myogenic potentials: The cross-check principle revisited. *Journal of the American Academy of Audiology*.

The vestibular evoked myogenic potential (VEMP) is commonly used to evaluate the function of the saccule and inferior vestibular nerve. It has been reported that up to 40% of patients over age 60 fail to generate a VEMP (Su et al. 2004). When this occurs it is difficult to determine whether the absent VEMP represents evidence of bilateral impairment, or, whether the absent responses represent a normal age-related variant (i.e. an idiopathic absence). In this report we have invoked the cross-check principle, described by Jerger and Hayes (1976) as a method of addressing this diagnostic dilemma. We suggest that another sonomotor response, the post-auricular muscle potential (PAM), could be used to determine whether a bilaterally absent VEMP represents true impairment.

Hood, L.J. (2008). Approaches to hearing evaluation in young patients: Learning what we need to know before a child can tell us. Proceedings of the 2007 International Conference on Pediatric Audiology, Chicago, Illinois.

Early identification of hearing loss through widespread newborn hearing screening allows management of hearing loss to begin during the critical early period after birth. The literature supports the importance of early identification of hearing loss and implementation of management in a timely manner (e.g., Yoshinaga-Itano et al., 1998). Key to this process is the ability to accurately and efficiently quantify hearing sensitivity in infants, just the group of patients who cannot provide reliable behavioral responses to test stimuli. Objective methods, such as ABR and high-rate ASSR, are valuable tools in pediatric diagnostic testing. Whether one begins with behavioral or physiologic methods, depending on the age of the patient, the use of a test battery and the cross-check principle is a critical part of a thorough evaluation. Protocols should contain a combination of physiologic and behavioral test methods. The results from all of the measures need to agree based on current audiologic knowledge. It is critical to use strict procedural and interpretation criteria and "objectify" test methods and interpretation of physiologic and behavioral responses as much as possible. Methods where the examiner is blinded to the presence of a stimulus, as with some computer-driven systems, in behavioral testing serve to make behavioral testing

and decisions about the presence of a response more objective. Equally important is assuring that physiologic test methods are administered in a technically correct manner and accurately interpreted. Comprehensive evaluation of hearing should ultimately include behavioral testing when an infant reaches an age when accurate behavioral assessment is feasible. However, in the meantime, physiologic testing provides appropriate and comprehensive information that is sufficient to initiate management early in an infant's life and assure maximal auditory development.

Jacobson, G.P., McCaslin, D.L., Grantham, S.L., and **Piker, E.G.** (In press). Significant vestibular system impairment is common in a cohort of elderly patients referred for assessment of falls risk. *Journal of the American Academy of Audiology*.

Falls in elderly patients are associated with morbidity, mortality and cost to the health care system. The development of falls risk assessment programs have represented a method of responding to what is known about injurious falls. The multidimensional assessments involve the comparison against normative data of a patient's performance on metrics known to influence the likelihood of future falls. The factors assessed usually include: falls and medication history, measures of mentation, depression, orthostatic hypotension, simple or choice reaction time, gait stability, postural stability and the integrity of the patient's vision, somesthetic and vestibular senses.

This investigation was conducted to measure the proportion of patients referred for falls risk assessment who have evidence of vestibular system impairment. This study represented a qualitative, retrospective review of data collected from 2003-2007. The cohort was 185 consecutive patients referred for multidimensional assessments of falls risk. Patients underwent quantitative assessments of peripheral and central vestibular system function consisting of electro- or video- nystagmography (i.e. ENG/VNG), and sinusoidal harmonic acceleration testing. Results of these tests were compared to normative data. We found that 73% of the sample who underwent vestibular system assessment had quantitative evidence of either peripheral or central vestibular system impairment. Our results suggest that quantitative assessments of the vestibulo-ocular reflex should be conducted on patients who are evaluated for falls risk. These examinations should include at least caloric testing and, where available, rotational testing.

Jacobson, G.P., McCaslin, D.L., and Kaylie, D.M. (In press). Alexander's Law revisited. *Journal of the American Academy of Audiology*.

Alexander's law (AL) describes the phenomenon where spontaneous nystagmus (SN) shows its greatest slow phase velocity when gaze is directed toward the fast phase of the nystagmus beat. The nystagmus attenuates as gaze deviates away from the direction of the fast phase. Nystagmus that follows AL usually denotes the presence of a unilateral peripheral vestibular system impairment. A third element of AL (not described by Alexander, 1912) is that the SN will intensify when vision is denied. Two cases are described herein. Case 1 is an example where AL occurs due to a unilateral vestibular system impairment. The patient demonstrates a unidirectional SN that intensifies in the vision-denied condition. Case 2 illustrates AL due to a tumor compressing the brainstem and cerebellum. This patient has an asymmetric gaze evoked nystagmus that does not intensify in the vision-denied condition. In both cases the nystagmus intensifies when gaze is directed toward the direction of the nystagmus fast phase. The mechanisms underlying AL are described. Although, usually AL occurs in acute peripheral vestibular system lesions, it can occur in cases of central nervous system disease. The key element is whether the SN that follows AL is attenuated or augmented in the vision-denied condition.

Johnson, E.E. (2008). Dispensing rates of four common hearing aid product features: Contributions of audiologist, patient population, and hearing aid characteristics, as well as evidence-based practice recommendations to variations in practice. Ph.D. Dissertation completed under the direction of **T.A. Ricketts**.

This study demonstrated sizeable variability in dispensing rates of four common hearing aid product features (i.e. digital feedback suppression processing, digital noise reduction processing, directional processing, and the telecoil) among 257 audiologists similar to that previously evidenced in a 2007 annual hearing aid dispenser survey. The purpose of this study was to account for such demonstrated variability, and resultantly, a variety of variables with a potential relationship to dispensing rates were evaluated. In general, these evaluations indicated that characteristics of the audiologists and the hearing aids they dispense were more strongly related to dispensing rates of each feature than patient population characteristics. However, variability in the dispensing rates of each feature was accounted for by only several specific variables. The most commonly occurring were:

- the price/level of hearing aid technology dispensed by the audiologist,
- an audiologist-specific feature candidacy criterion for when to recommend a product feature based on patient need, and
- an audiologist's amount of personal belief in the potential benefit of a product feature.

Specific to directional processing, beliefs held by an audiologist were not related to his/her dispensing rates, however, two other variables were:

- the magnitude of the audiologist's patient population's need for the feature based on communication difficulty in challenging listening environments
- the style of hearing aids most often dispensed by the audiologist.

Meanwhile, those audiologists with AuD degrees were shown to dispense digital noise reduction processing 10% more often than those with a Master's degree. Lastly, one major study finding was that evidence-based practice recommendations were not reflected in audiologists' dispensing rates of the four product features.

McCaslin, D.L., and **Jacobson GP.** (In press). Current role of the VNG examination in the context of the multidimensional balance function test battery. *Seminars in Hearing*.

The present report provides a description of the place that the ENG/VNG examination plays in the assessment of vertigo, dizziness and unsteadiness. The primary areas addressed are: 1) the identification of disorders of ocular motility, 2) the identification of clinically significant positional and positioning nystagmus and vertigo, 3) the identification of unilateral and bilateral peripheral vestibular system impairments and 4) the identification of central vestibular system impairment.

McCaslin, D.L., Jacobson, G.P., Talent, A.F., and **Jackson, C.G.** (March, 2007). Vestibular evoked myogenic potential (VEMP) abnormalities in a sample of 41 patients with posterior fossa lesions. Annual Meeting of the American Auditory Society, Scottsdale, AZ.

The present report describes our experience recording the VEMP in 41 patients with unilateral space occupying lesions in the posterior fossa. Of the total, 90% were vestibular schwannomas, 7% were meningiomas and one was a epidermoid cyst. Additionally, 37% were small (i.e. $\leq$ 1.5 cm), 46% medium (i.e. > 1.5 cm and $\leq$ 2.9 cm) and 17% were large-sized tumors (i.e. $\geq$ 3.0 cm). VEMP, caloric tests and auditory brainstem response (ABR) tests were conducted in most cases. The VEMP was absent on the affected side in 49% of the cases. The P13-N23 amplitude asymmetry was abnormal in another 5 (i.e. 12%, using a 0.47 asymmetry upper limit) or 9 (i.e. 22%, using a 0.35 asymmetry upper limit) of the patients producing a total of between 61%-71% VEMP amplitude abnormalities in this sample. Where it

was recorded there were no significant differences between P13 latencies from the affected and unaffected ears. Increases in tumor size did not produce systematic reductions in VEMP amplitude. Caloric abnormalities were observed in 68% of the sample although at times (17%) the VEMP results were not in agreement. These findings suggest that inferior vestibular nerve impairments are common occurrences in posterior fossa tumors.

McKay, S., Gravel, J.S., and **Tharpe, A.M.** (2008). Amplification considerations for children with minimal or mild bilateral hearing loss or unilateral hearing loss. *Trends in Amplification*, 12: 43-54.

Children with minimal or mild bilateral hearing loss and unilateral hearing loss are at higher risk for academic, speech-language, and social-emotional difficulties than their normal hearing peers. The choice to fit infants with moderate or greater degrees of bilateral hearing loss has been standard practice for most clinicians, but for those with minimal or mild bilateral hearing loss or unilateral hearing loss, the fitting of hearing technology must be based on limited data. Evidence does not yet exist to support all the management decisions that an audiologist must make upon identifying an infant with minimal or mild bilateral hearing loss or unilateral hearing loss. It is not yet known which children are at the greatest risk for educational problems nor is it known if the provision of early amplification in this population will help a child avoid later difficulties. Some of these considerations and current hearing technology options for children with minimal or mild bilateral hearing loss or unilateral hearing loss are reviewed in this article.

Mueller, H.G., **Hornsby, B.**, and Weber, J. (In press). Using trainable hearing aids to examine real-world preferred gain. *Journal of the American Academy of Audiology*.

Background: While there have been many studies of preferred hearing aid gain in the real world, little data are available from participants using hearing aids with today's special features activated. Moreover, there only has been minimal preferred gain data collected using a trainable hearing aid.
Purpose: To determine if real-world preferred hearing aid gain with modern hearing aids was in agreement with previous work in this area, and to determine if the starting programmed gain setting influenced the outcome.
Research Design: An experimental crossover study. Participants were randomly assigned to one of two treatment groups. Following initial treatment, each subject crossed to the opposite group and experienced that treatment.
Study Sample: Twenty two adults with downward sloping sensorineural hearing loss served as participants (mean age 64.5; 16 males, 6 females). All were experienced users of bilateral amplification.
Intervention: Using a crossover design, participants were fitted to two different prescriptive gain conditions: VC start-up 6 dB above NAL-NL1 target or VC start-up 6 dB below NAL-NL1 target. The hearing aids were used in a 10-14 day field trial for each condition, and using the VC, the participants could "train" the gain to their preferred level. During the field trial hearing aid use was logged, as well as the listening situations experienced by the listeners based on the hearing instrument's acoustic scene analysis. The participants completed a questionnaire at the start and end of each field trial in which they rated loudness perceptions, and their satisfaction with aided loudness levels.
Results: Because several participants potentially experienced floor or ceiling effects for the range of trainable gain, the majority of the statistical analysis was conducted using 12 of the 22 participants. For both VC-start conditions, the trained preferred gain differed significantly from the NAL-NL1 prescriptive targets. The initial start-up gain significantly influenced the trained gain; the median preferred gain for the +6 dB start condition was 8 dB higher than the preferred gain for the -6 dB start condition (See Figure A-1). Deviation from NAL-NL1 target was not significantly influenced by the time spent in different listening environments, amount of hearing aid use during the trial period, or amount of hearing loss.

Questionnaire data showed more appropriate ratings for loudness and higher satisfaction with loudness for the 6 dB below target VC-start condition (See Figure A-2 for Loudness ratings).
Conclusions: The initial programmed gain of the hearing instruments can influence preferred gain in the real world.

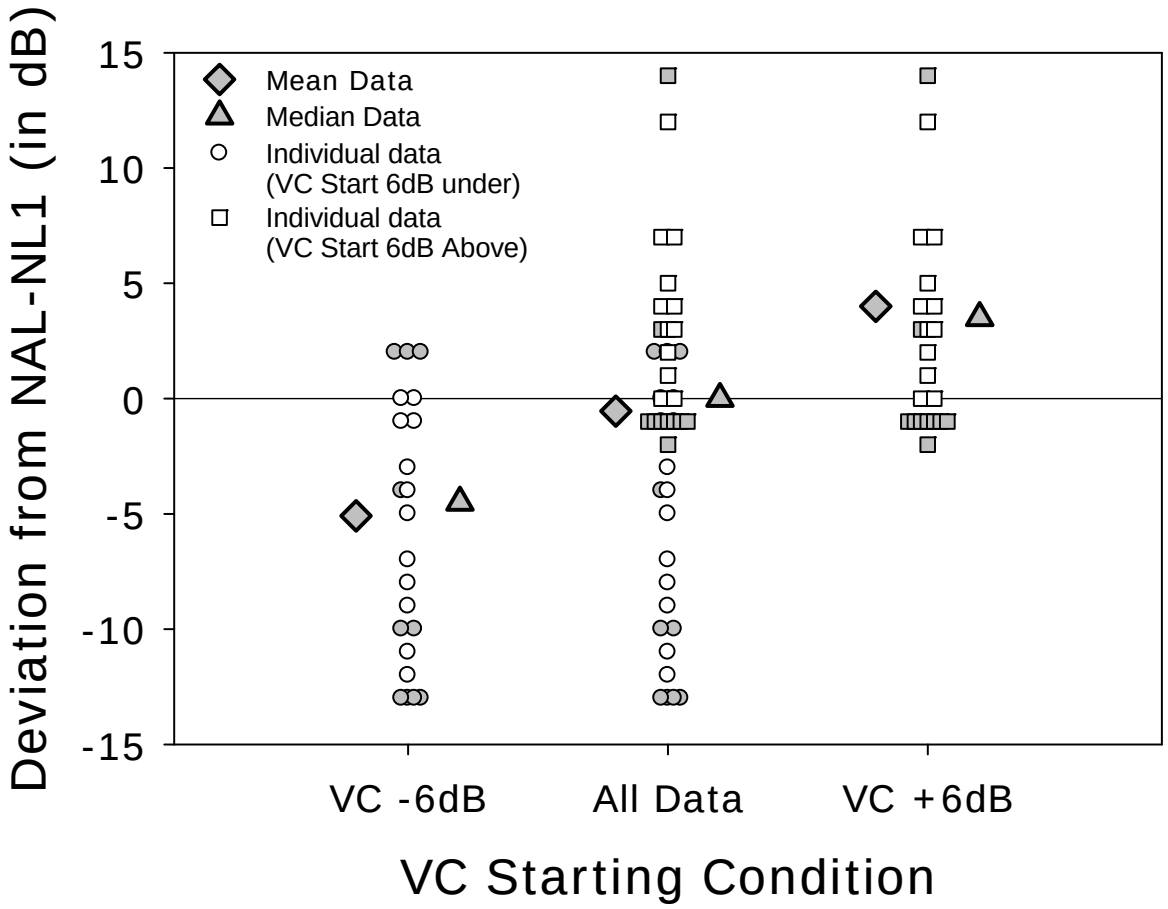

Figure A-1. Individual, mean and median preferred gain results displayed as a function of the VC-start condition (+6 dB versus -6 dB). Pooled data also are shown. Grey circles or squares represent individuals who were eliminated from the statistical analysis because of possible floor or ceiling effects. Mueller *et al.*

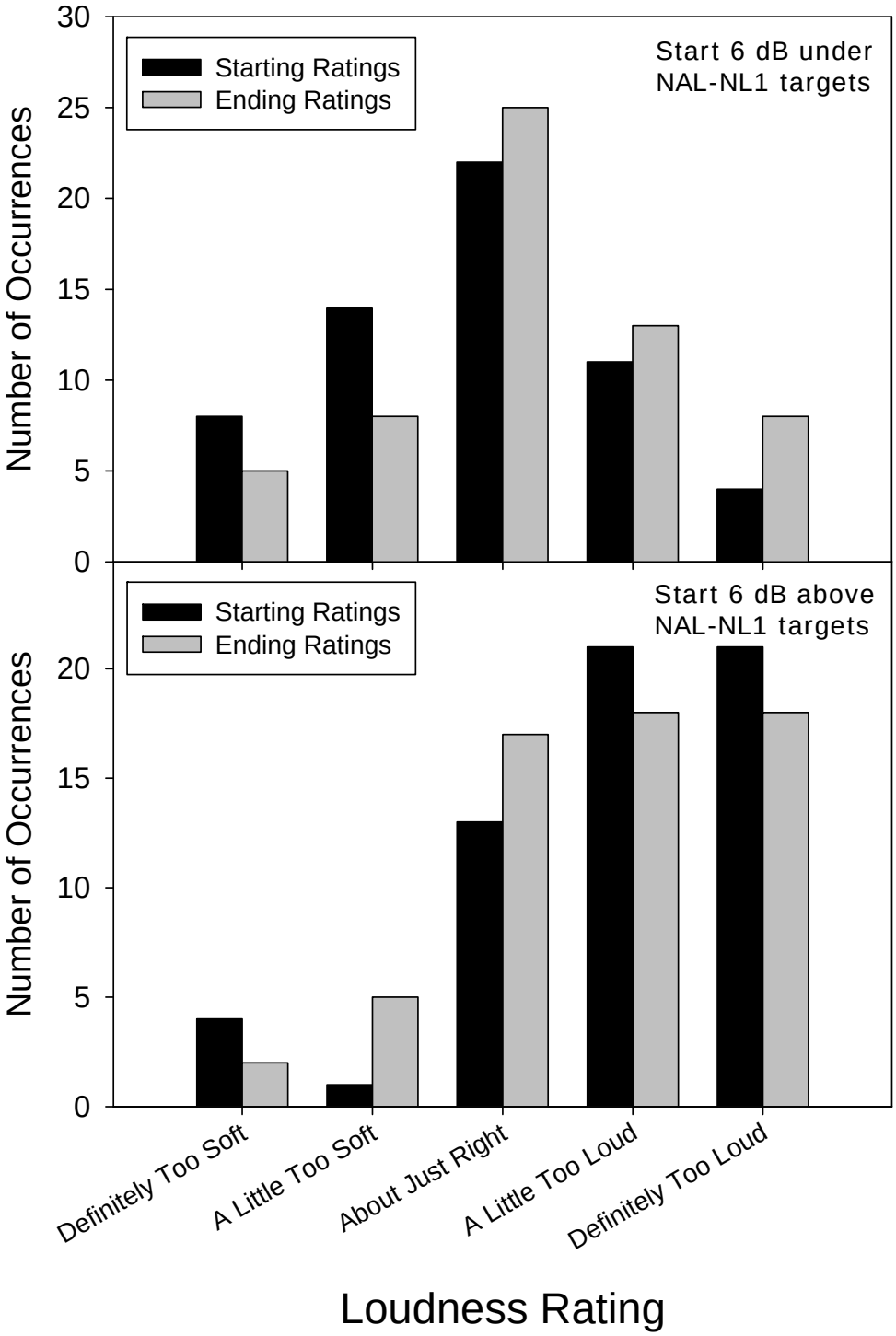

Figure A-2. Distribution of the overall loudness ratings from the five questions completed during the field trial (12 subjects, 5 questions, 60 total observations). Results shown for the beginning and ending of the field trial for both the 6 dB under (upper panel) and 6 dB over (lower panel) starting gain conditions. Mueller *et al.*

Piker, E.G., Jacobson, G.P., McCaslin, D.L., Grantham, S.G. (2008). Pschological comorbidities and their relationship to self-reported handicap in samples of dizzy patients. *Journal of the American Academy of Audiology* 19, 337-347.

Conventional vestibular system tests assess impairment. However, other factors such as depression, anxiety, and somatic/autonomic symptoms and differences in coping strategies are known to impact dizziness handicap. We studied these factors in an unselected group of 63 patients seen in our balance disorders clinic. Results showed that, in our patient sample, co-morbid conditions occurred more than has been reported in normals. No differences in co-morbities were found between patients with and without vestibular system impairments. Gender was a significant factor as women reported more symptoms and greater handicap. Escape/Avoidance coping had the strongest positive correlation with self-perceived dizziness handicap. These findings suggest that self-assessment measures represent a unique piece of information important for the assessment and treatment of dizzy patients.

Porter, H.L., Neely, S.T., and Gorga, M.P. (In press). Using benefit-cost ratio to select universal newborn hearing screening test criteria, *Ear and Hearing*.

Current Universal Newborn Hearing Screening (UNHS) protocols presumably use criteria that are chosen on the basis of the hit and false-alarm rates they produce. Such an approach emphasizes test performance, but does not include societal implications of the benefit of early identification. For this reason, we examined an alternative method of evaluating test performance and selecting criteria for use in UNHS programs that is designed to include societal implications. Existing data from over 1200 ears were used to analyze benefit-cost ratio (BCR) as a function of Distortion Product Otoacoustic Emissions (DPOAE) level. Estimates of the prevalence of congenital hearing loss identified through UNHS in 37 states and U.S. territories in 2004 were used to calculate BCR. Exact benefits and costs are difficult to know. As such, a range of estimates for the lifetime monetary benefits and yearly costs for UNHS was used based on data available in the literature. Both one-step (DPOAE alone) and two-step screening (DPOAE followed by ABR) paradigms were considered in the calculation of BCR. DPOAE level may be reduced in cases in which middle-ear effusion is present; therefore, an additional BCR analysis was performed considering this effect.

Our calculations indicated that for a range of proposed benefit and cost estimates, the monetary benefits of a one-step newborn hearing screening (NHS) program outweighed programmatic costs. One observation was that maximum BCR remained stable regardless of the somewhat “hypothetical” programmatic cost and benefit of early identification. That is, the BCR is robust in that it can be applied regardless of the values that are assigned to benefit and cost (Figure A-3). The inclusion of secondary ABR testing increased the BCR, but did not alter the DPOAE criterion level at which maximum BCR occurred (Figure A-4). The presence of middle-ear effusion reduces overall DPOAE level, subsequently lowering the DPOAE criterion level required for maximum BCR. Though the use of screening criteria that maximize BCR resulted in lower test sensitivity compared to other criteria, BCR may be used to select criteria that result in increased test sensitivity and still provide a high, though not maximal, BCR. Using BCR analysis provides a framework in which the societal implications of NHS protocols may be considered and emphasizes the value of UNHS. In addition, BCR analysis suggested that UNHS is a worthwhile investment for society, as benefits always outweigh costs, at least for the estimations included in this paper. Though some of the benefits of early identification of hearing impairment cannot be estimated through a monetary analysis, such as improved psychosocial development and quality of life, this paper provided an alternative to selecting UNHS protocols which included a consideration of the societal implications of UNHS screening criteria.

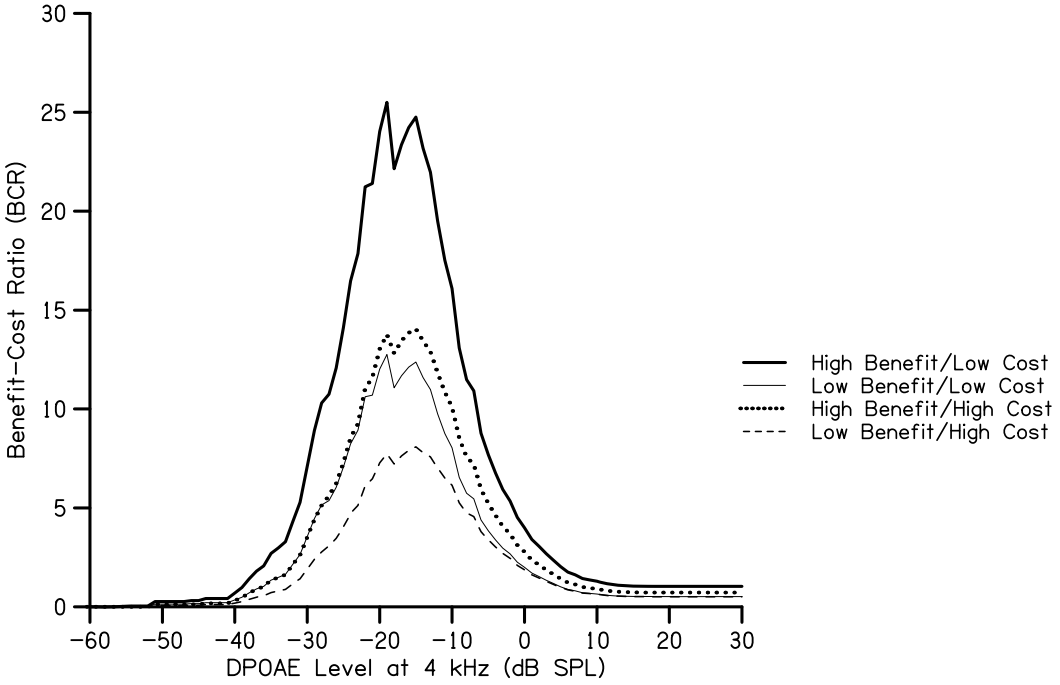

Figure A-3. BCR as a function of DPOAE level at 4 kHz. The parameter in this figure is the estimate used for benefit and for cost. These estimates of lifetime costs and monetary benefits take into account prevalence estimates for 37 states and territories in U.S. in 2004 as reported by the CDC. Porter *et al.*

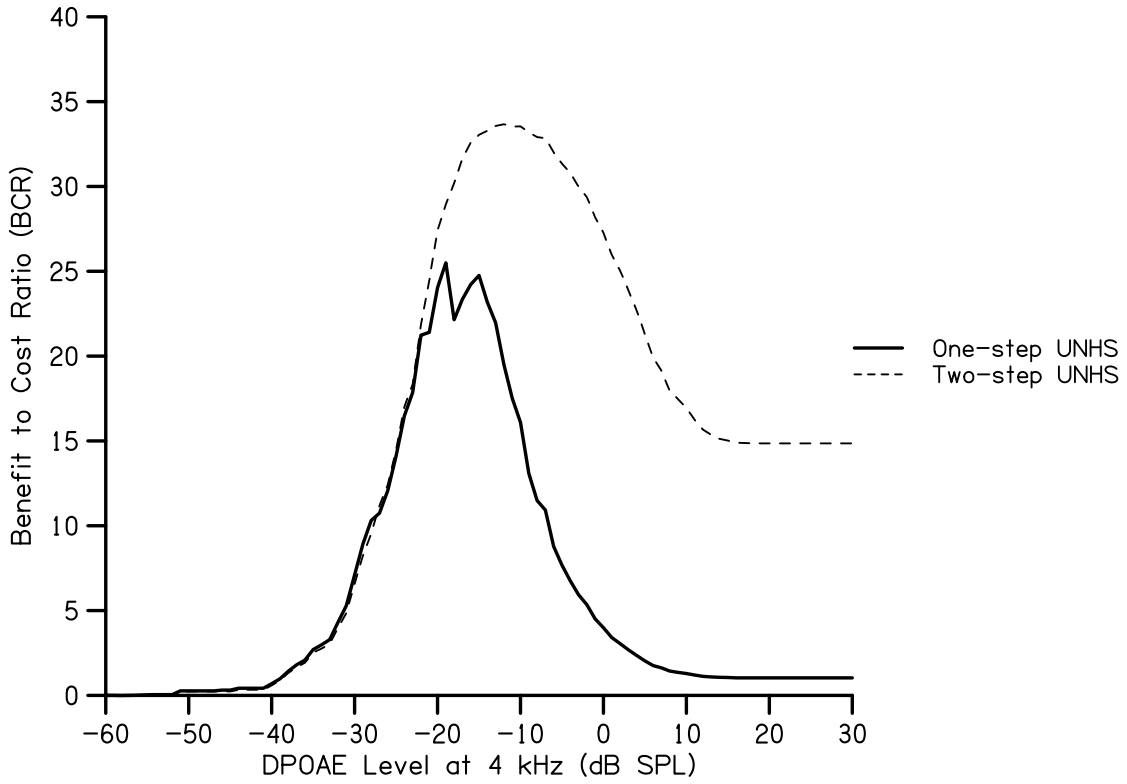

Figure A-4. BCR as a function of DPOAE level at 4 kHz for two different screening protocols. BCR for the one-step protocol is derived from the scenario in which benefit is high and cost is low (as shown in Fig. A-x). BCR for a two-step protocol uses ABR as the second step and is based on estimated referral rates. Porter *et al.*

Tharpe, A.M. (2008). Auditory integration training: The magical mystery cure. Presented at Paediatric ENT and Audiology Conference, Durban, South Africa.

Over the past decade, audiologists, speech-language pathologists, and others have debated the contribution of auditory integration training (AIT), also known as auditory enhancement training and audio-psycho-phonology. Initial anecdotal reports suggested that AIT, when used with individuals having diagnoses of autism, pervasive developmental disorders, learning difficulties, attention deficit disorder, and dyslexia, resulted in reduced hyperacusis, increased attention span, better eye contact, more social awareness, fewer tantrums, increased verbalizations, improved auditory comprehension, and improved articulation. As a result of those reports, in 1994 the American Speech-Language-Hearing Association (ASHA) Subcommittee on Auditory Integration Training of the Ad Hoc Committee on Auditory Integration and Facilitated Communication published a report that reviewed the existing data on AIT. At that time, because the primary data sources were nonrefereed journals and anecdotal reports, the committee recommended that AIT be considered an experimental treatment and that consumers be notified of such before receiving services (ASHA, 1994). This presentation reviewed the efficacy data for AIT.

Tharpe, A.M. (2008). A comparison of home- and center-based intervention settings for infants and toddlers with hearing loss. Presented at the EHDI National Convention, New Orleans, LA.

Research has shown that early intervention efforts conducted in the home with care providers can result in significant increases in developmental skill acquisition for children who are at high risk, disadvantaged, and with previously diagnosed conditions. However, the studies that have been conducted thus far looking at home-based versus center-based intervention have not included children with hearing loss. Unlike children with many other handicapping conditions, children with hearing loss are unique in their reliance on an optimized acoustic environment in order to develop communication and pre-academic skills in an oral modality. In order to achieve early speech and language skills, infants and toddlers must have acoustic accessibility to the speech and language models in their environment. It is currently not known if the acoustic environments encountered in typical homes are conducive or detrimental to communication development in infants and toddlers with hearing loss. Because of the difficulty in ensuring consistent acoustic accessibility in typical home environments, infants and toddlers with hearing loss and their families may experience better communication outcomes when early intervention is conducted in a center-based environment, where acoustic conditions can be controlled. The objectives of this study were (1) to develop a best-practices early intervention strategy for children with hearing loss and their families and (2) to conduct research designed to determine the efficacy of center-based versus home-based early intervention services for infants and toddlers with hearing loss. Families were randomized into either the center-based or home-based intervention program. Pretest data were collected from the families and children at the time of enrollment and outcome variables were measured every three months thereafter until age three. At that point, children transitioned to school-based services. Preliminary data from outcome measures in the areas of auditory skills, speech-language ability, emergent literacy, and family quality of life were presented.

Tharpe, A.M. (2008). Minimal hearing loss in children: The facts and the fiction. Presented at Paediatric ENT and Audiology Conference, Durban, South Africa.

Since the early 1980s, audiologists have become increasingly aware of the potential impact of even mild degrees of hearing loss on the psychoeducational and psychosocial outcomes of children. The high academic failure rates of children with unilateral and mild bilateral hearing loss have triggered investigations into speech/language, cognitive, and behavioral characteristics of these children. This presentation described some of the key research findings that have led us to our current thinking about minimal hearing loss in children. Specifically, the demographics of minimal and mild hearing loss, including unilateral hearing loss, in young children were presented and future research needs were discussed. Finally, recommended assessment and management strategies for this population were provided.

Tharpe, A.M. (2008). Unilateral and mild bilateral hearing loss in children: Past and current perspectives. *Trends in Amplification*, 12:7-15.

Since the early 1980s, audiologists have become increasingly aware of the potential impact of even mild degrees of hearing loss on the psychoeducational and psychosocial outcomes of children. This review describes some of the key research findings over the past several decades that have led us to our current thinking about unilateral and mild bilateral hearing loss in children. The first section addresses unilateral hearing loss (UHL) and is followed by a review of the mild bilateral hearing loss (MBHL) literature. Specifically, the issues addressed include (1) the significance of permanent mild degrees of hearing loss on psychoeducational and psychosocial development of children, and (2) the

speech, language, and auditory characteristics of children with mild degrees of hearing loss. Finally, some recommendations regarding the direction of future research are offered.

Tharpe, A.M., Ashmead, D.A., Sladen, D.P., **Ryan, H.**, and Rothpletz, A.M. (In press). Visual attention and hearing loss: Past and current perspectives. *Journal of the American Academy of Audiology*.

It is reasonable to expect that deaf individuals require the use of vision for purposes other than those needed by hearing persons. For example, without the use of hearing, one would need to scan the environment visually to determine if someone was approaching rather than listening for footsteps or a name being called. Furthermore, these experiential differences could alter the development of neural organization of sensory systems of deaf persons. Studies of visual attention in deaf individuals have been mixed in their conclusions about whether this altered organization results in better or worse visual attention abilities by those who are deaf relative to those with normal hearing. We have implemented a series of visual attention studies utilizing several paradigms including the Continuous Performance Task, the Letter Cancellation Task, the Flanker Task, and a self-designed task of target identification in the periphery under distracter and non-distracter conditions. Collectively, these studies have pointed to a compensatory role that the visual system plays for deaf individuals. Specifically, the visual system appears to play an important role in directing a deaf individual's attention to the near visual periphery.

Tharpe, A.M., Eiten, L., and Gabbard, S. (2008). Hearing technology for children with mild and unilateral hearing loss. *Seminars in Hearing*, 29(2):169-177.

Much attention has been given to the potential difficulties encountered by children with permanent unilateral and minimal or mild bilateral hearing loss. Psychoeducational and psychosocial problems have been well-documented in a large percentage of these children. However, audiologists remain concerned about the appropriate application of hearing technologies with children with these mild degrees of losses and the effectiveness of these technologies. Concerns generally center on which of these children should use hearing technology, which technologies are most effective, and how the technology should be fitted. Furthermore, audiologists are uncertain about when children should be fit with hearing technology. This review of hearing technologies used with children who have permanent unilateral, or minimal or mild bilateral hearing loss is intended to serve as a guide to audiologists when considering possible technology options and fitting configurations. It is clear that hearing technology decisions must be made on a child-by-child basis taking into consideration each child's unique set of listening needs and obstacles.

Tharpe, A.M., and Sladen, D.P. (2008). Causation of permanent unilateral and mild bilateral hearing loss in children. *Trends in Amplification*, 12: 17-25.

Children with permanent unilateral or mild bilateral hearing loss have been a focus of concern by audiologists, educators, and physicians for at least 2 decades. These children are known to be at risk for psychoeducational difficulties. However, despite this concern, little has been learned about the causative factors of these hearing losses and how those factors might be contributing to child development. This review of known causes of permanent unilateral and mild bilateral hearing loss in children is meant to draw attention to the importance of the search for etiologic factors. That is, the identification of the hearing loss should not signal the end of the diagnostic process but, rather, the beginning of a search for causation. With the combined efforts of audiologists, otolaryngologists,

pediatricians, geneticists, and other medical professionals, we may enhance our understanding of the primary causes of unilateral and mild bilateral hearing loss and, perhaps, create links between causative factors and psychosocial and psychoeducational outcomes.

B. Hearing Science — Basic

Croghan, N. B. H., **Grantham, D. W.,** Camalier, C., and **Ashmead, D. H.** (March, 2009). Binaural interference in the free field. Poster presented at the annual meeting of the American Auditory Society, Scottsdale, AZ

In an anechoic chamber the minimum audible angle (MAA) was measured in five normal-hearing adults for a narrow band of noise centered at 4000 Hz (the target). In the absence of an interfering stimulus, average MAA for the target was 2.3°. When a low-frequency distracter (a narrow band of noise centered at 500 Hz) was pulsed on and off with the target from directly in front of the subject, average MAA was significantly elevated (12.6°). However, if the distracter was continuously present, or if it consisted of two independent noises presented from ±90°, interference was practically abolished (Figure B-1). The interference effect was asymmetric: a pulsed high-frequency distracter did not result in elevation of MAA threshold for a low-frequency target. These results are similar to those that have been extensively reported for stimuli presented under headphones [e.g., Bernstein and Trahiotis, J. Acoust. Soc. Am. **98**, 155-163 (1995)]. Results from the current study are consistent with the notion that interference from a spectrally remote low-frequency distracter occurs in the free field to the extent that the target and distracter are fused into a single perceptual object. [Supported by NIH/NIDCD T35-DC008763.]

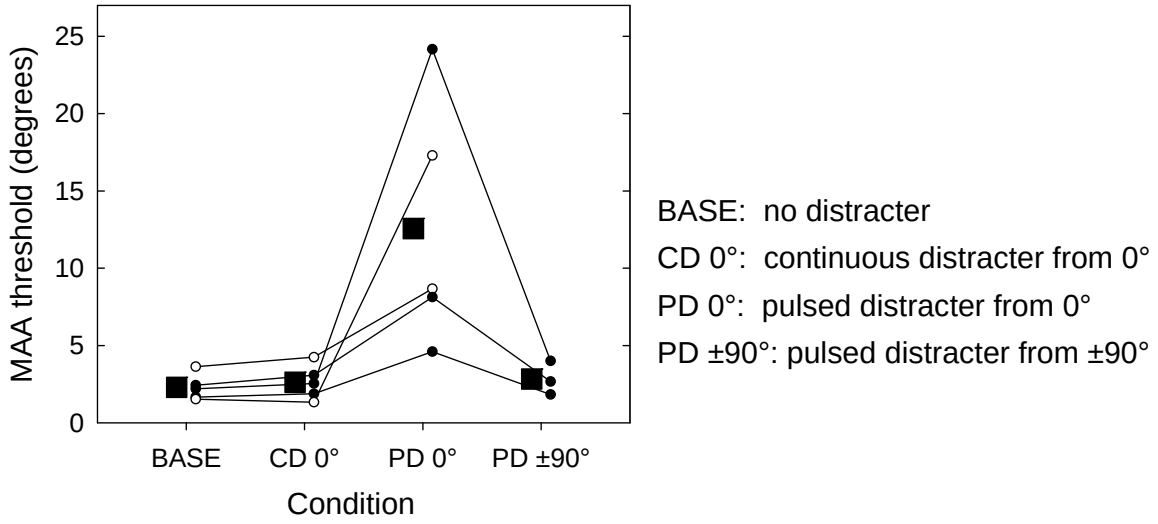

Figure B-1. MAA thresholds for a band of noise centered at 4000 Hz in the presence of a distracter band centered at 500 Hz. Data for individual subjects are shown as the small circles. Large filled squares indicate mean thresholds across listeners. Conditions shown along abscissa are identified in the legend. Grantham *et al.*, 2009.

Federman, J., and **Ricketts, T.A.** (2008). Preferred listening levels for musicians using in-ear monitors. *Journal of Speech, Language and Hearing Research*, 51(1):147-59.

This study examined the impact that changing on-stage music and crowd noise levels during musical performance had on preferred listening levels (PLLs) and minimum acceptable listening levels (MALLs) across both floor and in-ear monitors. Participants for this study were 23- to 48-year-old musicians, with

and without hearing loss, who had 10 years of musical training or comparable professional experience. For this study, PLLs and MALLs were established for the musician's own voice, whereas the levels of other onstage musical signals were systematically varied. PLLs for in-ear monitors were found at significantly lower levels than for floor monitors (approximately 0.6 dB). The results of this study indicated that PLLs for in-ear monitors were at significantly lower levels than for floor monitors (approximately 0.6 dB). However, despite large spectral differences, PLLs across the 2 monitor types were small enough that the same recommended exposure time would be advocated based on National Institute for Occupational Safety and Health and Occupational Safety and Health Administration recommendations. MALL data also indicated significantly lower levels (approximately 6.0 dB) when musicians were using in-ear monitors in comparison to floor monitors. The much larger difference suggests that musicians' risk of noise exposure may be reduced by the use of in-ear monitors. However, given the similar PLL results and known monitor output levels, proper counseling would likely be required before this potential advantage would be realized.

Federman, J., and **Ricketts, T.A.** (In preparation). Effects of audibility and musical training on music perception and cognition tasks.

This study examined the impact of musical training, audibility, hearing loss and amplification on music perception and cognition. Participants for this study included 40 adults aged 21 to 72 with and without musical training and with and without hearing loss. Two experiments were completed. In the first, 32 participants were divided into 4 groups based on musical training and hearing status. Participants were tested behaviorally on the Montreal Battery of Evaluation of Amusia (MBEA) and the Advanced Measures of Music Audiation (AMMA) tests in low and high audibility conditions. In the second experiment, eight participants with no musical training or hearing loss aged 21-32 were tested in three levels of audibility (33%, 66%, and 100%). For half the participants, audibility was limited by attenuating presentation level (25, 35, and 60 dB SPL); for the other half, audibility was limited by low pass filtering the test signals (500, 2000, or 8000 Hz). For Experiment 1, scores on the MBEA and AMMA were significantly higher for those with musical training. In addition, participants with normal hearing performed better than those with hearing loss on subtests of scale, interval, and memory, as well as on both AMMA subtests. Audibility was only a significant factor for the scale subtest. For Experiment 2, there were no significant effects of audibility, or method of audibility limiting.
Results suggest that musical training results in superior performance on the MBEA and AMMA tests, and that such training mitigates the effects of hearing loss on music cognition. Moreover, with one exception (scale), audibility did not significantly impact performance suggesting hearing aids may not be useful for alleviating the negative effects of hearing loss on music perception and cognition. However, increased audibility may be found to impact sound quality or timbre discrimination in future studies.

Galster, J.A. (2008). The use of reverberation time as an indicator of speech intelligibility in a reverberation chamber and two larger rooms. Ph.D. Dissertation completed under the direction of **T.A. Ricketts**.

This project investigated speech recognition in rooms of different size with similar average reverberation times. A comparative analysis of existing literature has provided evidence to support that speech recognition in small rooms may be poorer than in larger rooms when the two spaces have a similar amount of reverberation. This study evaluated speech recognition using sentences binaurally recorded using an acoustic manikin in three rooms of different volume and/or dimension. The three rooms included a small reverberation chamber (48 m3) a university lecture hall (479 m3) and a high school band practice room (474 m3). Speech recognition was tested using bilateral insert earphones in two groups of 13 participants with normal-hearing and moderate to severe hearing impairment. Testing was completed at

five signal to noise ratios for each group. Physical measures of each room's acoustics included: mean free path, frequency specific reverberation time, Speech Transmission Index.

This investigation determined that listeners in both groups showed a significant decrease in speech recognition performance with poorer signal to noise ratios and a significant effect of room size. The poorest speech recognition was measured in the smallest room. There was no interaction between signal to noise ratio and room type for either of the two participant groups. The effect of both change in room size and signal to noise ratio correlated well with changes in Speech Transmission Index (r2 = 0.95).

A single, time varying rationale was introduced as a source of the room size specific reverberation effects. This theory speculates that the period during which early reflections are beneficial to speech understanding may decrease with as room size increases. This increased growth rate of a room's reverberant field is consistent with measures of decreased mean free path in smaller rooms. In addition the reverberant field of a small room will contain more reflections than a larger room when the two are matched for reverberation time. It is proposed that the increased number of overlapping reflections also contributes to decreases in speech recognition ability.

Grantham, D.W., Ashmead, D.H., Ricketts, T.R., Labadie, R.F., and **Haynes, D.S.** (2007). Horizontal-plane localization of noise and speech signals by post-lingually deafened adults fitted with bilateral cochlear implants. *Ear and Hearing*, 28, 524-541.

Objectives: The main purpose of the study was to assess the ability of adults with bilateral cochlear implants to localize noise and speech signals in the horizontal plane. A second objective was to measure the change in localization performance in these adults between approximately 5 and 15 months post activation. A third objective was to evaluate the relative roles of interaural level difference (ILD) and interaural temporal difference (ITD) cues in localization by these subjects.
Design: Twenty-two adults, all post-lingually deafened and all bilaterally fitted with MED-EL COMBI 40+ cochlear implants, were tested in a modified source identification task. Subjects were tested individually in an anechoic chamber, which contained an array of 43 numbered loudspeakers extending from –90° to +90° azimuth. On each trial a 200-ms signal (either a noise burst or a speech sample) was presented from one of 17 active loudspeakers (span: ±80°), and the subject had to identify which source from the 43 loudspeakers in the array produced the signal. Subjects were tested in three conditions: left device only active, right device only active, and both devices active. Twelve of the 22 subjects were re-tested approximately 10 months after their first test. In experiment 2, the spectral content and rise-decay time of the noise stimulus were manipulated.
Results: The relationship between source azimuth and response azimuth was characterized in terms of the adjusted constant error ($\hat{\mathbf{C}}$). (1) With both devices active, $\hat{\mathbf{C}}$ for the noise stimulus varied from 8.1° to 43.4° (mean: 24.1°). By comparison, $\hat{\mathbf{C}}$ for a group of listeners with normal hearing ranged from 3.5° to 7.8° (mean: 5.6°). When subjects listened in unilateral mode (with one device turned off), $\hat{\mathbf{C}}$ was at or near chance (50.5°) in all cases. See Figures B-2 and B-3. However, when considering unilateral performance on each subject's better side, average for the speech stimulus was 47.9°, which was significantly (but only slightly) better than chance. (2) When listening bilaterally, error score was significantly lower for the speech stimulus (mean = 21.5°) than for the noise stimulus (mean = 24.1°). (3) As a group, the 12 subjects who were re-tested 10 months after their first visit showed no significant improvement in localization performance during the intervening time. However, two subjects who performed very poorly during their first visit showed dramatic improvement (error scores were halved) over the intervening time. In experiment 2, removing the high-frequency content of noise signals resulted in significantly poorer performance, but removing the low-frequency content or increasing the rise-decay time did not have an effect.

Conclusions: In agreement with previously reported data, subjects with bilateral cochlear implants localized sounds in the horizontal plane remarkably well when using both of their devices, but they generally could not localize sounds when either device was deactivated. They could localize the speech signal with slightly, but significantly better accuracy than the noise, possibly due to spectral differences in the signals, to the availability of envelope ITD cues with the speech but not the noise signal, or to more central factors related to the social salience of speech signals. For most subjects the remarkable ability to localize sounds has stabilized by five months post-activation. However, for some subjects who perform poorly initially, there can be substantial improvement past five months. Results from experiment 2 suggest that ILD cues underlie localization ability for noise signals, and that ITD cues do not contribute.

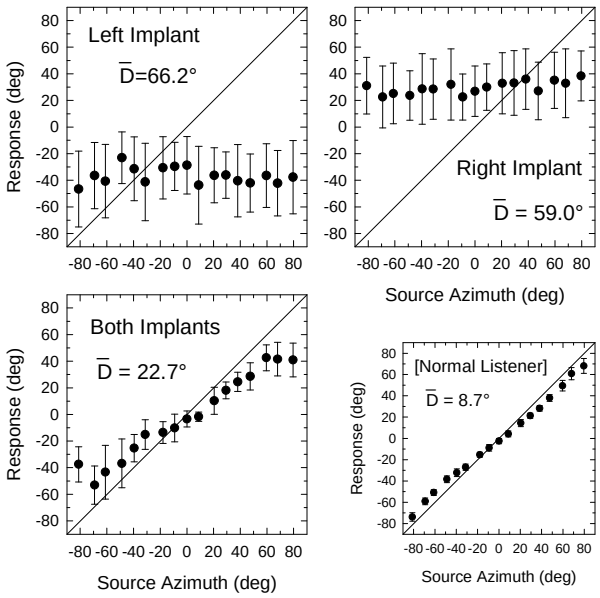

Figure B-2. Localization responses for subject B listening in LEFT, RIGHT, and BOTH devices conditions for the SPEECH stimulus. Inset at lower right shows data for the same stimulus from a listener with normal hearing. Grantham *et al.* (2007).

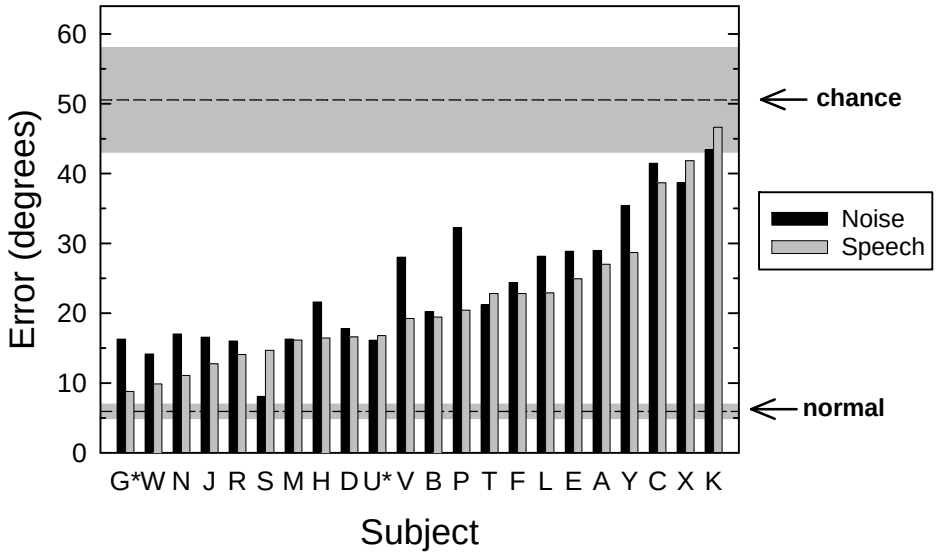

Figure B-3. Adjusted constant error scores ($\hat{C}$) for all subjects when listening in bilateral mode, for both the NOISE and SPEECH stimulus. Chance performance is indicated by the upper horizontal line, with the shaded area indicating ±1.96 standard deviations around the mean. The lower horizontal line shows the mean for 9 listeners with normal hearing, with the shaded area indicating the 95% confidence interval. Grantham *et al.* (2007).

Grantham, D.W., Ashmead, D.H., Ricketts, T.R., Haynes, D.S., and **Labadie, R.F.** (2008a). Interaural time and level difference thresholds for acoustically presented signals in post-lingually deafened adults fitted with bilateral cochlear implants using CIS+ processing. *Ear and Hearing*, 29, 33-44.

Objectives: The main purpose of the study was to measure thresholds for interaural time differences (ITDs) and interaural level differences (ILDs) for acoustically presented noise signals in adults with bilateral cochlear implants. A secondary purpose was to assess the correlation between the ILD and ITD thresholds and error scores in a horizontal-plane localization task, to test the hypothesis that localization by individuals with bilateral implants is mediated by the processing of ILD cues.
Design: Eleven adults, all post-lingually deafened and all bilaterally fitted with MED-EL COMBI 40+ cochlear implants, were tested in ITD and ILD discrimination tasks in which signals were presented acoustically through headphones that fit over their two devices (Figure B-4). The stimulus was a 200-ms burst of Gaussian noise bandpass filtered from 100-4000 Hz. A two-interval forced-choice adaptive procedure was employed in which the subject had to respond on each trial whether the lateral positions of the two sound images (with the interaural difference favoring the left and right sides in the two intervals) moved from left-to-right or right-to-left.
Results: In agreement with previously reported data, ITD thresholds for the subjects with bilateral implants were poor. The best threshold was ~400 μs, and only five of eleven subjects tested achieved thresholds less than 1000 μs. In contrast, ILD thresholds were relatively good; mean threshold was 3.8 dB with the initial compression circuit on the implant devices activated and 1.9 dB with the compression deactivated. The ILD and ITD thresholds were higher than previously reported thresholds obtained with direct electrical stimulation (generally < 1.0 dB and 100-200 μs, respectively). When the data from two outlying subjects were omitted, ILD thresholds were highly correlated with total error score in a

horizontal-plane localization task, computed for sources near midline ($r = 0.87$, $p < 0.01$). See Figure B-5.

Conclusions: The higher ILD and ITD thresholds obtained in this study with acoustically presented signals (as compared to prior data with direct electrical stimulation) can be attributed – at least partially – to the signal processing carried out by the cochlear implant in the former case. The processing strategy effectively leaves only envelope information as a basis for ITD discrimination, which, for the acoustically presented noise stimuli, is mainly coded in onset information. The operation of the compression circuit reduces the ILDs in the signal, leading to elevated ILD thresholds for the acoustically presented signals in this condition. The large magnitude of the ITD thresholds indicates that ITDs could not have contributed to the performance in the horizontal-plane localization task. Overall, the results suggest that for subjects using bilateral implants, localization of noise signals is mediated entirely by ILD cues, with little or no contribution from ITD information.

Figure B-4. Photograph of one of the subjects showing the normal position of the cochlear implant (left) and the positioning of the headphones over the implant (right). Reprinted with permission. Grantham *et al.* (2008a).

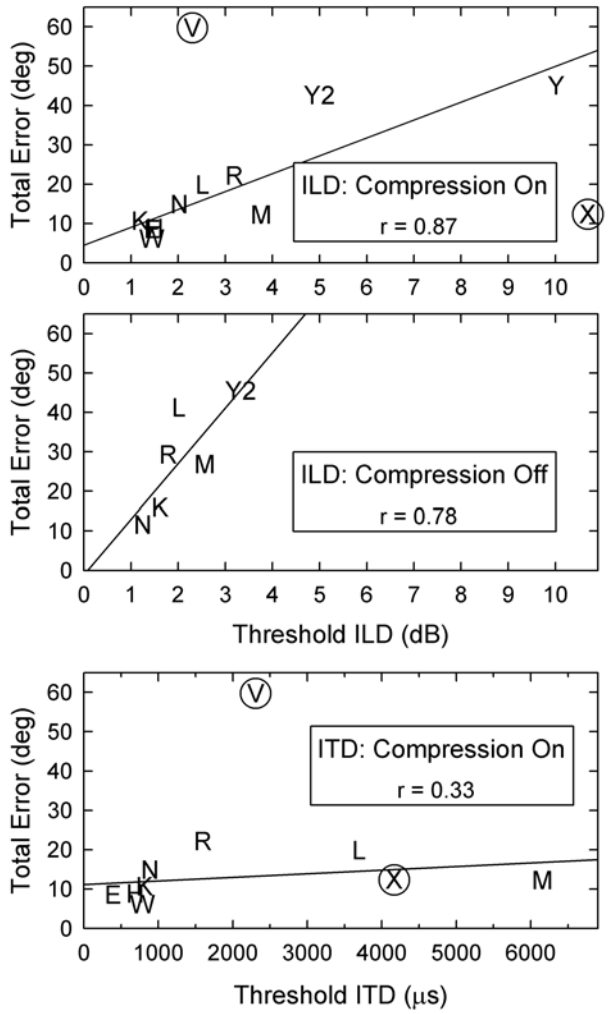

Figure B-5. Total rms error in the localization task ($\overline{D}$) vs. threshold interaural differences measured under headphones for 11 subjects. The three panels are for the three conditions tested. The best-fitting lines and the correlation coefficients (r) shown in the upper and lower panels were computed discounting the data from the outlying subjects X and V (whose data points are circled – see text). The localization data are from Grantham *et al.* (2007).

Grantham, D.W., Ricketts, T.R., Ashmead, D.H., Labadie, R.F. and **Haynes, D.S.** (2008b). Localization by post-lingually deafened adults fitted with a single cochlear implant. *The Laryngoscope*, 118, 145-151.

Objective: The main purpose of the study was to assess the ability of adults with unilateral cochlear implants to localize noise and speech signals in the horizontal plane.
Design: Six unilaterally implanted adults, all post-lingually deafened and all fitted with MED-EL COMBI 40+ devices, were tested in a modified source identification task. Subjects were tested individually in an anechoic chamber, which contained an array of 43 numbered loudspeakers extending from –90° to +90° azimuth. On each trial a 200-ms signal (either a noise burst or a speech sample) was presented from one

of 9 active loudspeakers, and the subject had to identify which source (from the 43 loudspeakers in the array) produced the signal.
Results: The relationship between source azimuth and response azimuth was characterized in terms of the adjusted constant error ($\hat{C}$). $\hat{C}$ for three subjects was near chance (50.5°), while $\hat{C}$ for the remaining three subjects was significantly better than chance (35°-44°). By comparison, $\hat{C}$ for a group of normal-hearing listeners was 5.6°. For two of the three subjects who performed better than chance, monaural cues were determined to be the basis for their localization performance.
Conclusions: Some unilaterally implanted subjects can localize sounds at a better than chance level, apparently because they can learn to make use of subtle monaural cues based on frequency-dependent head-shadow effects. However, their performance is significantly poorer than that reported in previous studies of bilaterally implanted subjects, who are able to take advantage of binaural cues.

Grantham, D.W., Ricketts, T.A., and **Ashmead, D.H.** (July, 2008c). The effect of a speech target's motion on its recognition in the presence of simultaneous competing sentences. *JASA* 123, 3457(A). Presented at the 155th Meeting of the Acoustical Society of America, Paris.

Prior knowledge of where to listen significantly improves speech recognition of target sentences presented in the presence of distracter sentences coming from different locations [G. Kidd et al., *J. Acoust. Soc. Am.* 118, 3804-3815 (2005)]. The present study extended the work of Kidd et al. by measuring the effect of a target's motion on its recognition when competing messages are present. In an anechoic chamber normal-hearing subjects were presented with three simultaneous sentences from the CRM corpus and were instructed to indicate key words from the target sentence (identified by a call-sign previously known to the subject). In the stationary condition the three sentences came from -60°, 0°, and +60° azimuth. In the moving condition, the target source moved through a 60° arc during its on-time, centered at one of the three designated azimuths, while the two distracter sentences were stationary at the other two azimuths. In both cases, subjects either knew in advance where the target would be (Certain Condition) or did not know (Uncertain Condition). We hypothesized that motion of the target would result in a release from informational masking.

For targets off midline (at ±60°) motion facilitated recognition, supporting our hypothesis. However, for targets at midline (0°), motion *degraded* performance, contrary to our hypothesis (Figure B-6). Possibly the effect of motion itself on recognition interacts with the changing spatial separation between target and interferers during a motion trial. That is, for a moving target at midline, the spatial separation between target and one of the side interferers at target offset would be smaller than for the comparable stationary target, thus overcoming any potential advantage of motion *per se*. For targets at the peripheral azimuths that move laterally, the spatial separation from the center interferer would become larger during the presentation, thus enhancing any advantage due to motion *per se*. Further work is underway to tease apart the contributions of these potential factors.

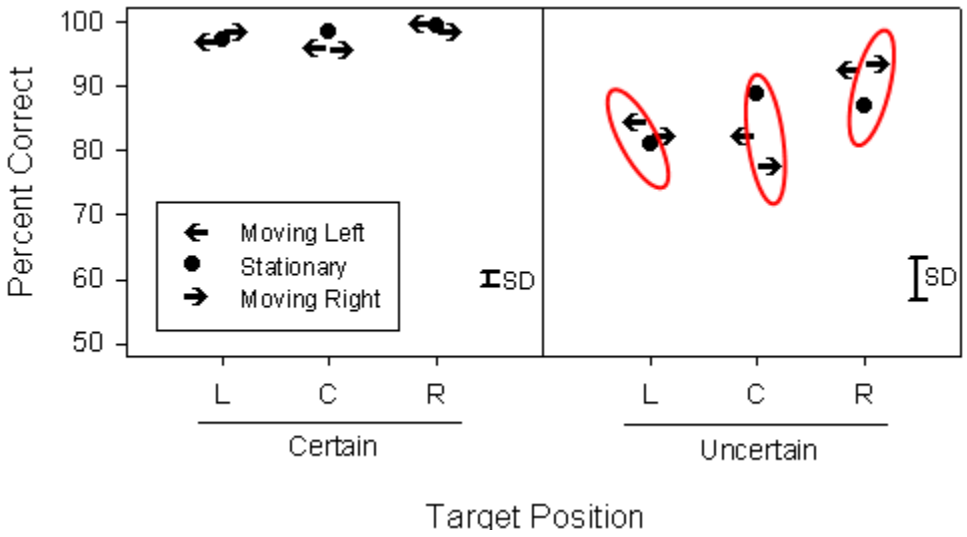

Figure B-6. Percent correct recognition (averaged across four subjects) for targets presented from three locations (Left, Center, Right), under conditions of Target Location Certainty (left panel) or Uncertainty (right panel). Targets could be stationary, moving left, or moving right, as indicated in the legend. Pairs of encircled data points are significantly different from each other. Grantham *et al.* (2008c).

Grantham, M.A.M. (May, 2008). Attention allocation with approaching auditory events. Ph.D. Doctoral dissertation completed under the direction of **D.A. Ashmead**, Vanderbilt University.

Every day and night, pedestrians cross streets as vehicles approach them from multiple directions. For most people, this is an easy task. However, for the blind or visually-impaired person, there is greater risk involved. For soldiers patrolling on foot along narrow streets with high vehicle traffic, the risk of being struck by an approaching vehicle at night or in low-vision conditions is also great. This risk is mainly due to a need to rely more fully on auditory information. This study aimed to add to the current body of knowledge surrounding how listeners in pedestrian-based scenarios, with eyes closed, judged on which side concurrent, approaching auditory events would pass them by.

The acoustic event stimuli panned across a circular loudspeaker array in an anechoic chamber, simulating either one or more linear motion paths approaching the listener from the front. Listener thresholds were recorded as the closest points of approach that these motion paths would have reached if they were to continue on a path which passed the listener by on the right or left.

Results indicate that listeners were able to attend to and judge the side of passage for the target motion path in the presence of a distinctly, spatially separate competing stationary or moving acoustic event, which they either judged or ignored. Listeners were also able to do this well whether the competing event temporally overlapped the endpoints, midportion, or entire primary event. However, target thresholds were poor when the competing event originated from the same direction as the target, then the target and competing events diverged toward opposite sides of passage. For similar angular velocities (6 to11 deg/s in this study), the range in magnitude of directional change (7 to12 deg) corresponding to the side of passage thresholds was similar but larger than that for the angular extent of motion required at threshold in minimum audible movement angle (MAMA) studies (2 to 5 deg). It is possible that, for approaching acoustic events, the additional change in distance-related sound level complicated listener perception of directional change.

Hornsby, B. W., and **Ricketts, T. A.** (2007a). Directional benefit in the presence of speech and speechlike maskers. J Am Acad Audiol 18(1): 5-16.

Recent research (Hornsby, Ricketts and Johnson, in press) suggests that omnidirectional hearing aids are relatively ineffective at improving speech understanding in everyday conversational speech settings when the background noise contains both energetic and informational masking components. The current study evaluated the benefits of directional technology in the presence of background noises that contained both energetic and informational masking components. Aided speech recognition (in both omnidirectional and directional modes) was assessed in the presence of three types of maskers (forward and reversed speech and speech modulated noise) that varied in the amount of informational masking they were expected to produce. Study results showed significant directional benefit in all conditions (See Figure B-7). This finding suggests that in everyday conversational speech environments directional technology is equally effective regardless of the magnitude of informational masking present in the background noise. In addition, study findings suggest that the semantic information present in the masking speech may play only a limited role in contributing to informational masking in everyday environments. See Figure B-8; compare HINT thresholds in forward speech maskers (semantic information present) and reversed speech maskers (no semantic information).

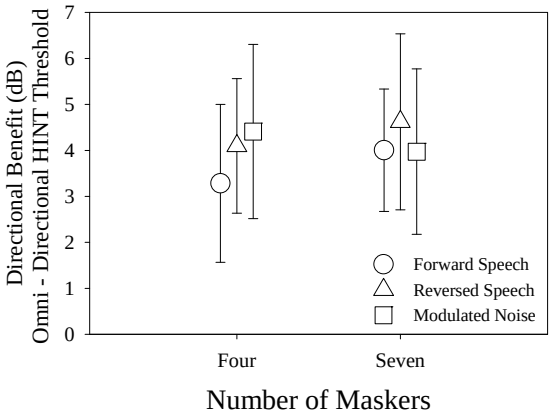

Figure B-7. Directional benefit (omni-directional thresholds for 50% sentence recognition) in dB SNR as a function of number of maskers (four or seven) and type of masking noise (forward speech, circles; reversed speech, triangles, and speech modulated noise, squares). Error bars represent one standard deviation. Positive values reflect better performance in directional mode. Hornsby & Ricketts (2007a).

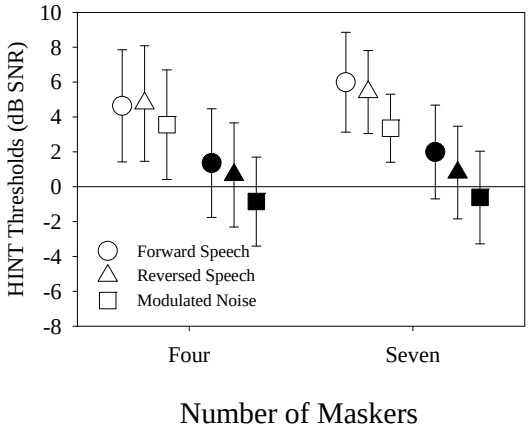

Figure B-8. Thresholds (in dB SNR) required for 50% sentence recognition for aided participants with hearing loss as a function of number of maskers (four or seven). Circles, triangles and squares represent performance in background noises of Forward Speech, Reversed Speech, and Modulated Noise, respectively. Performance in omnidirectional and directional modes is shown by the open and filled symbols, respectively. Error bars represent one standard deviation. Hornsby & Ricketts (2007a).

Hornsby, B. W., and **Ricketts, T. A.** (2007b). Effects of noise source configuration on directional benefit using symmetric and asymmetric directional hearing aid fittings. Ear Hear 28(2): 177-86.

Objective: The benefits of directional processing in hearing aids are well documented in laboratory settings. Likewise, substantial research has shown that speech understanding is optimized in many settings when listening binaurally. Although these past data suggest that speech understanding would be optimized using bilateral directional technology (e.g. a symmetric directional fitting), recent research suggests similar performance with an asymmetrical fitting (directional in one ear and omnidirectional in the other). The purpose of this study was to explore the benefits of using bilateral directional processing, as opposed to an asymmetric fitting, in environments where the primary speech and noise sources come from different directions.
Design: Sixteen older adults with mild-to-severe sensorineural hearing loss (SNHL) were recruited for the study. Aided sentence recognition using the Hearing in Noise Test (HINT) was assessed in a moderately reverberant room, in three different speech and noise conditions in which the locations of the speech and noise sources were varied (See Figure B-9). In each speech and noise condition speech understanding was assessed in four different microphone modes (bilateral omnidirectional mode; bilateral directional mode; directional mode left and omnidirectional mode right; omnidirectional mode left and directional mode right). The benefits and limitations of bilateral directional processing were assessed by comparing HINT thresholds across the various symmetric and asymmetric microphone processing conditions.
Results: Study results revealed directional benefit varied based on microphone mode symmetry (i.e. symmetric versus asymmetric directional processing) and the specific speech and noise configuration. In noise configurations in which the speech was located in the front of the listener and the noise was located to the side or surrounded the listener, maximum directional benefit (approximately 3.3 dB) was observed with the symmetric directional fitting. HINT thresholds obtained when using bilateral directional processing were approximately 1.4 dB better than when an asymmetric fitting (directional processing in only one ear) was used. When speech was located on the side of the listener, the use of directional processing on the ear near the speech significantly reduced speech understanding (See Figure B-10).

Conclusions: While directional benefit is present in asymmetric fittings (directional processing on only one ear), the use of bilateral directional processing optimizes speech understanding in noise conditions where the speech comes from in front of the listener and the noise sources are located to the side of or surround the listener. In situations where the speech is located to the side of the listener, the use of directional processing on the ear adjacent to the speaker is likely to reduce speech audibility and thus degrade speech understanding.

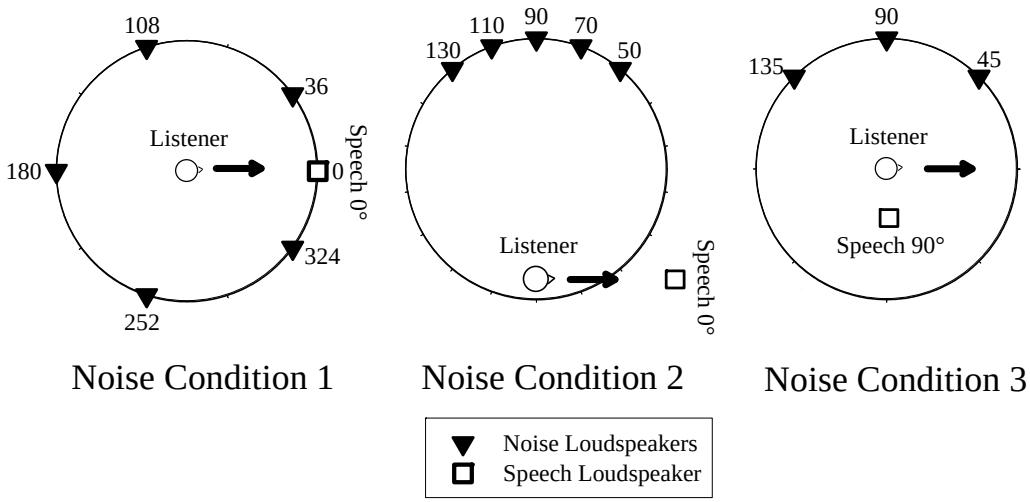

Figure B-9. Diagram of noise configurations used in the current study. Filled triangles represent noise loudspeaker positions. The open square represents the speech loudspeaker position and the open circle represents the listener position with the arrow showing the direction the listener was facing (forward in all conditions). Noise Conditions 1, 2 and 3 represent Speech Front-Noise Surround; Speech Front- Noise Side and Speech Side- Noise Side conditions, respectively. Hornsby & Ricketts (2007b).

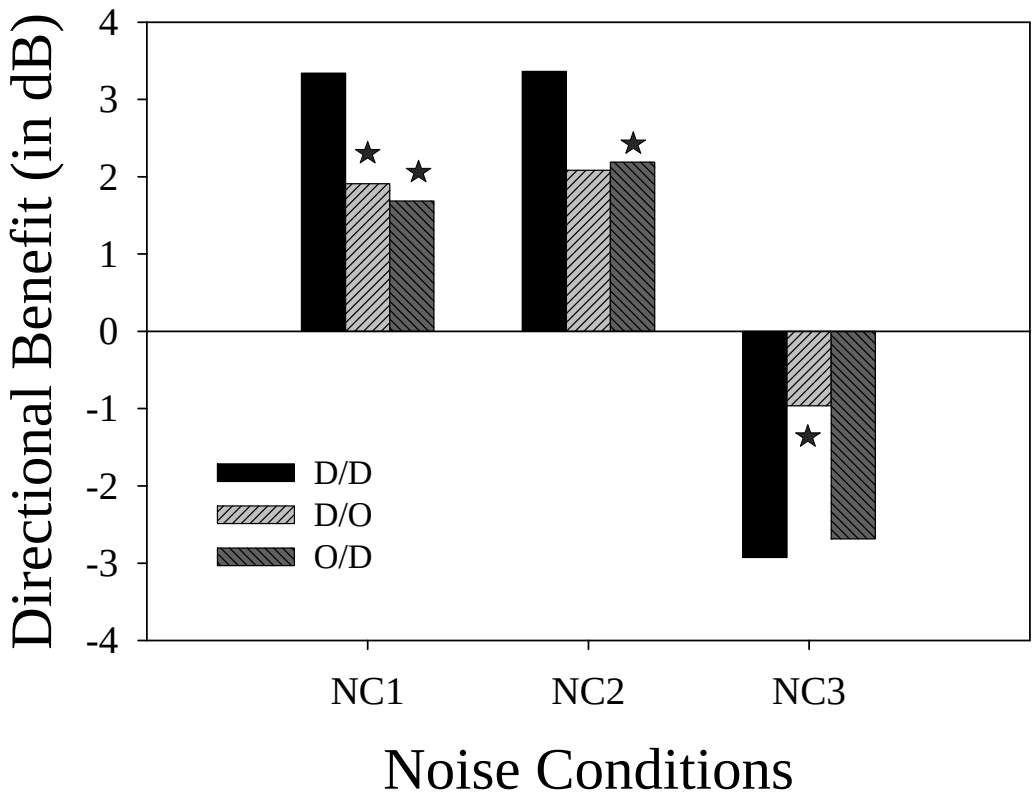

Figure B-10. Directional benefit (in dB) as a function of microphone mode (DD: bilateral directional mode; DO: directional mode left and omnidirectional mode right; OD: omnidirectional mode left and directional mode right). Positive values represent better performance in directional mode. Directional benefit is plotted separately for each noise configuration. NC1, 2 and 3 represent Speech Front-Noise Surround; Speech Front- Noise Side and Speech Side- Noise Side conditions, respectively. Stars above a bar show microphone mode configurations where directional benefit was significantly different (better or poorer) than that observed in the bilateral directional mode (D/D) condition. Hornsby & Ricketts (2007b).

Hornsby, B. W., and **Mueller, H. G.** (2008). User preference and reliability of bilateral hearing aid gain adjustments. J Am Acad Audiol 19(2): 158-70.

The purpose of the current study was to evaluate the consistency and reliability of user adjustments to hearing aid gain and the resulting effects on speech understanding. Sixteen, bilaterally aided, individuals with hearing loss adjusted their hearing aid gain to optimize listening comfort and speech clarity while listening to speech in quiet and noisy backgrounds. Following these adjustments, participants re-adjusted their aids to optimize clarity and comfort while listening to speech in quiet. These final gain settings were recorded and compared to those provided by NAL-NL1 prescriptive targets. In addition, speech understanding was tested with the hearing aids set at target and user gain settings. Performance differences between the gain settings were then assessed. Study results revealed that although some listeners preferred more or less gain than prescribed, on average, user and prescribed gain settings were similar in both ears (See Figure B-11). Some individuals, however, made gain adjustments between ears resulting in “gain mismatches”. These “mismatches” were often inconsistent across trials suggesting that

these adjustments were unreliable. Speech testing results, however, showed no significant difference across the different gain settings suggesting that the gain deviations introduced in this study were not large enough to significantly affect speech understanding (See Figure B-12).

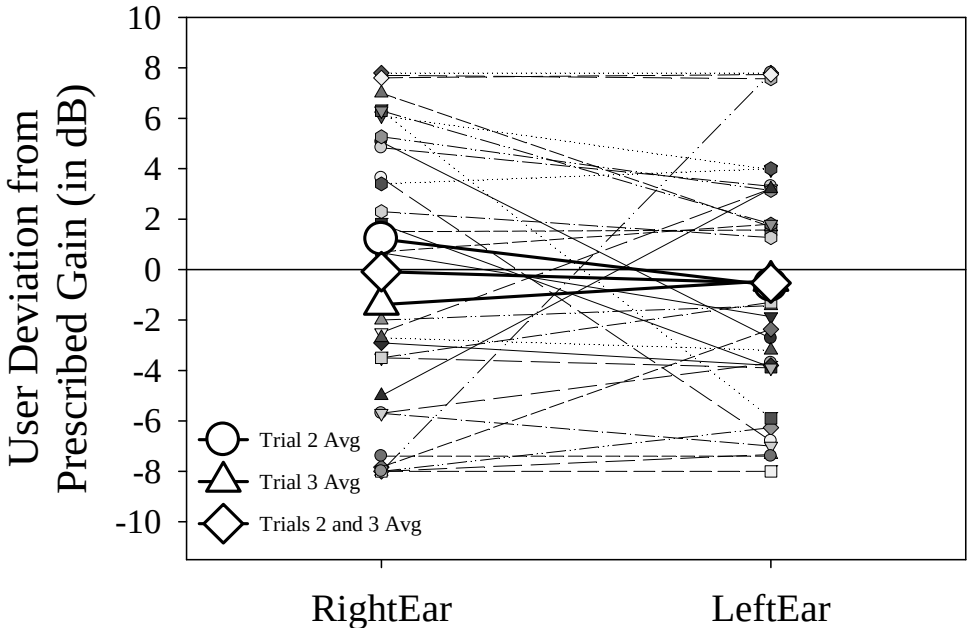

Figure B-11. Ear specific deviations, due to user adjustment of the hearing aid gain, from the best fit to prescribed gain settings. Large symbols represent average results while small symbols represent individuals on a given trial. Hornsby & Mueller (2008).

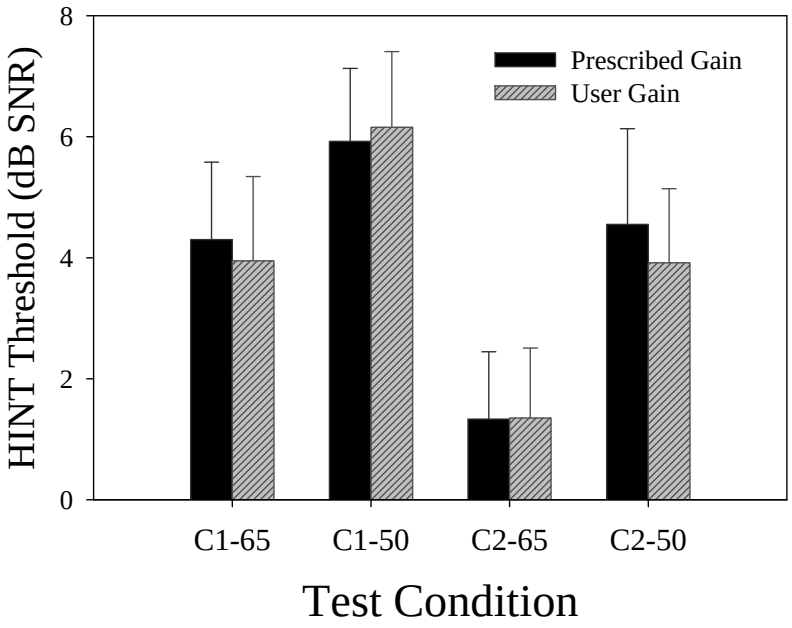

Figure B-12. HINT thresholds as a function of Noise Configuration (C1 = Noise Condition 1; Five noise speakers surrounding the listener and C2 = Noise Condition 2; Three noise speakers on the right side of the listener) and Noise level (65 or 50 dB A). Solid and striped bars show data obtained when participants listened with the aids set at clinician prescribed and user gain settings (i.e., following ear specific user adjustments to gain to optimize comfort and clarity), respectively. Hornsby & Mueller (2008).

Hornsby, B. and **Dundas, A.** (In press). Factors affecting prevalence estimates of dead regions in adults with hearing loss. Journal of the American Academy of Audiology.

Background: Recent work using the Threshold Equalizing Noise (TEN) test (Moore et al, 2000) as a gold standard, suggest that the presence of cochlear dead regions in persons with moderate-to-severe hearing loss may be quite common. In addition, results suggest that certain characteristics of hearing loss, such as severe-profound high-frequency loss or steeply-sloping configurations may be more commonly associated with positive TEN findings. However, only one study to date (Vinay and Moore, 2007b), has systematically evaluated the relationship between audiometric characteristics and TEN test findings on a large number of individuals with a wide range of hearing losses and hearing loss configurations and results of this study were limited to the frequency range of 500-4000 Hz.
Purpose: The purpose of this study was to further examine the effects of audiometric characteristics such as degree and slope of hearing loss on the rate of positive, negative and inconclusive findings on the TEN test over a wider frequency range (250-8000 Hz) than previously examined. Given that the functional impact of positive findings (i.e. findings suggestive of a dead region) may vary with the extent of potential damage, we were also interested in determining the relative occurrence of "patchy" versus contiguous positive findings on the TEN.
Research Design: Fifty-nine adults (117 ears) with a wide range of SNHL participated. To examine results over a wide frequency range (250-8000 Hz) the TEN (SPL), rather than the TEN (HL), was utilized. Thresholds, in both ears, were measured in quiet and in the TEN (SPL). Results were categorized as positive (suggestive of a dead region), negative (not suggestive of a dead region) or inconclusive.
Results: Positive test results among individuals with milder hearing losses (<60 dB HL) were common, suggesting a potential for false positive results. Consistent with past research, positive TEN (SPL) results were more common when hearing losses exceeded 60 dB HL, however, there was not a systematic

increase in positive results with increases in threshold (See Figure B-13). Also consistent with past research slope of hearing loss was an inadequate predictor of TEN (SPL) results. Negative results (not suggestive of a dead region) were less common in participants with steeply sloping losses while positive test findings were unaffected by hearing loss slope (See Figure B-14). Although a large proportion of participants had positive results on the TEN (SPL), for most participants, these positive findings occurred in isolated (i.e., one or two frequencies) rather contiguous frequency regions (See Figure B-15).
Conclusions: The large number of inconclusive results and the potential for false positive results makes interpreting the functional impact of TEN (SPL) results difficult, particularly when positive results are in the high (>4000 Hz) frequencies. In addition, although a large proportion (84%) of study participants had positive findings on the TEN (SPL), the functional impact of these findings is not clear as in the majority of cases, positive findings occurred at only one or two frequencies.

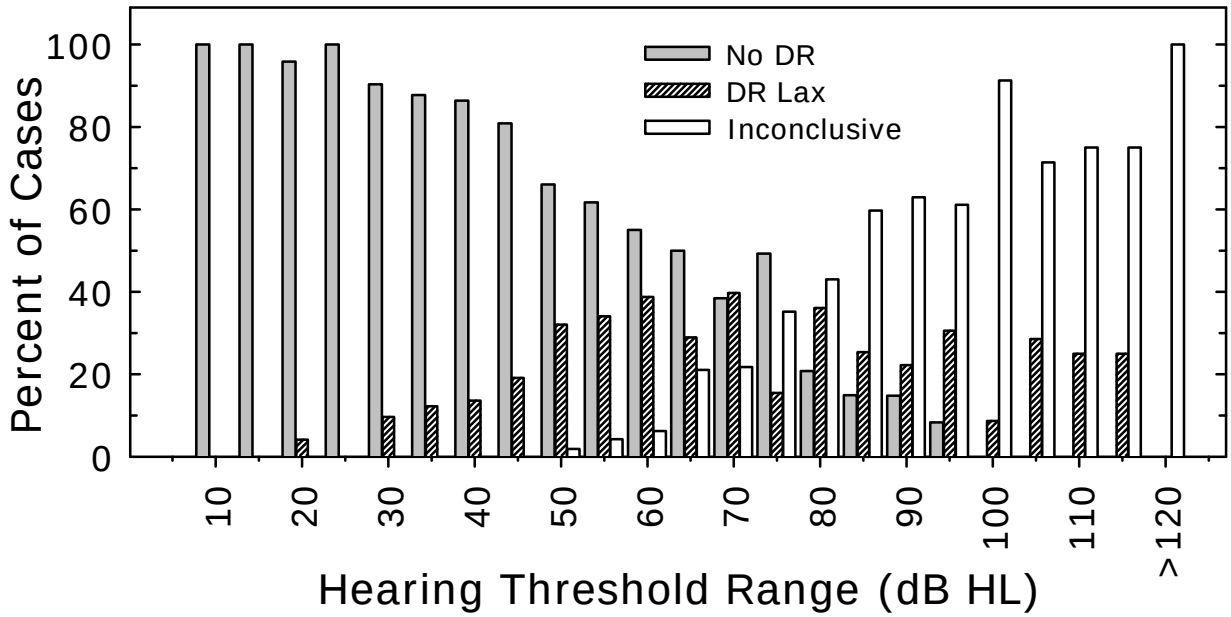

Figure B-13. Percent of cases of negative (No DR), positive (using a lax criterion) and inconclusive TEN (SPL) test results as a function of range of hearing thresholds. Hornsby & Dundas.

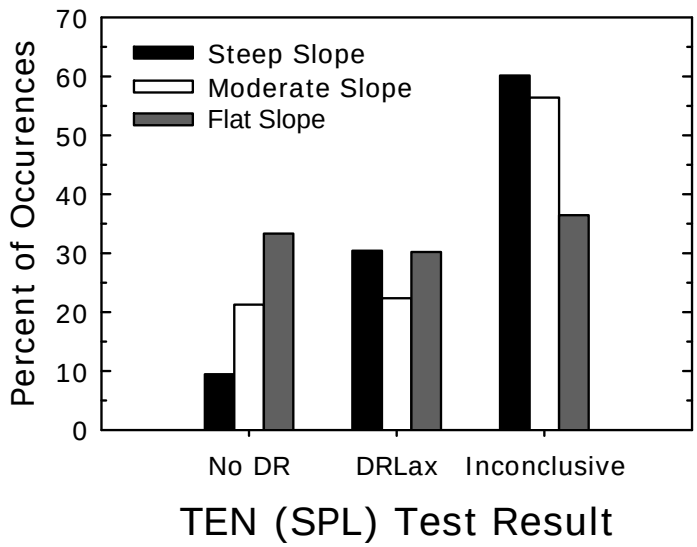

Figure B-14. Effect of hearing loss slope (Steep, moderate or flat) on negative, positive (Lax criterion) and inconclusive (for any reason) TEN (SPL) results in high-frequency (3000-8000 Hz) regions. Hornsby & Dundas.

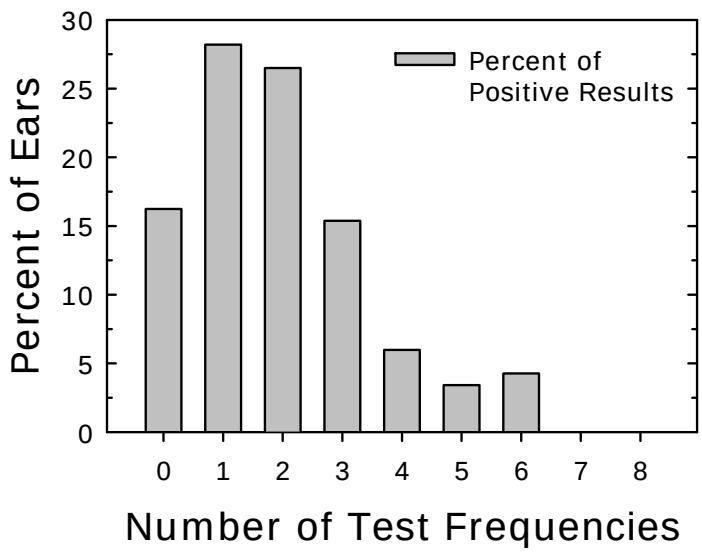

Figure B-15. Percentage of ears with positive TEN (SPL) findings at 0 (no positive findings) to eight (8) test frequencies (250, 500, 1000, 2000, 3000, 4000, 6000, and 8000 Hz). Hornsby & Dundas.

Hornsby, B. (June, 2008). Effects of noise configuration and type on binaural benefit with asymmetric directional fittings. Invited paper presented at the 155th Meeting of the Acoustical Society of America, Paris, France.

The benefits of bilateral directional processing for improving speech understanding in noise are well documented. However, these fittings are not universally accepted by hearing aid wearers. Research

suggests that an asymmetric fitting (omnidirectional in one ear/directional in the other) may provide benefit in noise comparable to symmetric directional fittings (directional in both ears). This study evaluated factors that may affect the relative benefit provided by an asymmetric directional fitting. Specific factors evaluated included noise configuration, reverberation and noise type.

Twenty individuals with mild-moderate SNHL participated. Aided HINT thresholds (SNR needed for 50% correct sentence recognition) in cafeteria babble were obtained in bilateral omnidirectional and directional modes and in an asymmetric mode in three (3) different noise configurations. Speech was always presented from the front at a 0° azimuth. Noise locations varied across conditions with 1) A "back loaded" condition (3 noise loudspeakers located at 105°, 255° and 180°); 2) A "Surround" condition (5 noise loudspeakers located at 45°, 105°, 180°, 255° and 315°), and 3) A "front loaded" condition (7 noise loudspeakers located at 30°, 45°, 105°, 180°, 255°, 315° and 330°). The specific noise configurations were chosen to systematically vary the difference in SNR between ears when switching between omni and directional microphone modes. This was done to examine the contribution of interaural SNR differences to the benefit seen with asymmetric directional fittings. Previous research on masking level differences has shown that the largest release from masking is seen in cases when the interaural SNR is equal. This suggests that asymmetric fittings may be problematic in noise conditions, such as when the noise comes primarily from the rear hemisphere, that lead to large differences in SNR between ears when in asymmetric mode. Measures were made in both an anechoic and reverberant (RT ~620 ms) environment. Reverberant environment was included under the assumption that reverberation could act to essentially increase the number and spatial location of the noise and, potentially, limit the negative effects of an asymmetric fitting. In a second experiment the effects of noise type were evaluated by comparing performance in symmetric and asymmetric modes in both steady state noise and cafeteria babble.

No significant interactions between room type (anechoic or reverberant) and any other factor were observed so results were averaged across rooms to highlight the effects of noise source configuration. Results suggest that noise configuration has a significant effect on the relative benefit provided by asymmetric fittings. Consistent with our initial hypothesis, asymmetric fittings appear to be most problematic (provide less benefit that a symmetric directional fitting) in the "back loaded" condition. Minimal differences were observed in the "front loaded" condition (See Figure B-16). In addition, analyses of individual data suggest that differences in bilateral directional benefit (symmetric fitting) also appear to have a significant effect on the reduction in benefit resulting from an asymmetric fitting. Individuals that receive the most benefit from a symmetric directional fitting are more likely to show significant decreases in performance when switching to an asymmetric fitting (See Figure B-17).

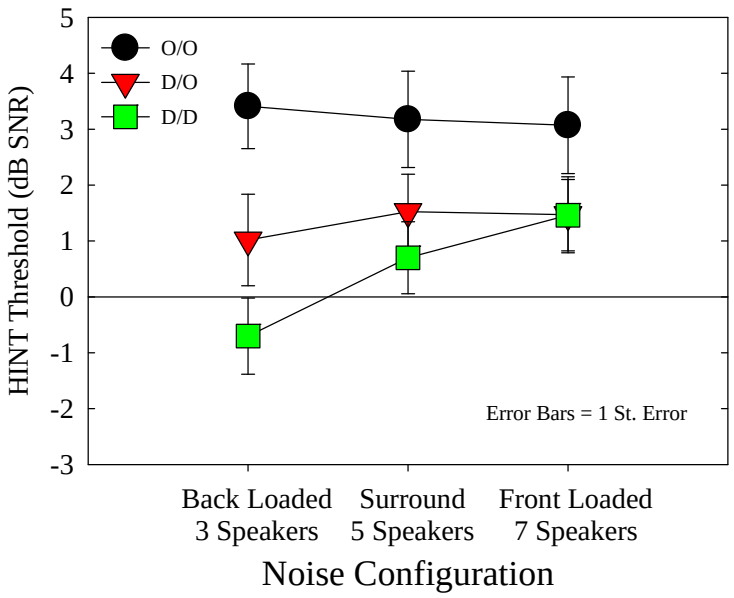

Figure B-16. HINT thresholds in symmetric omnidirectional (O/O), symmetric directional (D/D) and asymmetric (D/O) modes as a function of noise loudspeaker configuration. Hornsby (2008).

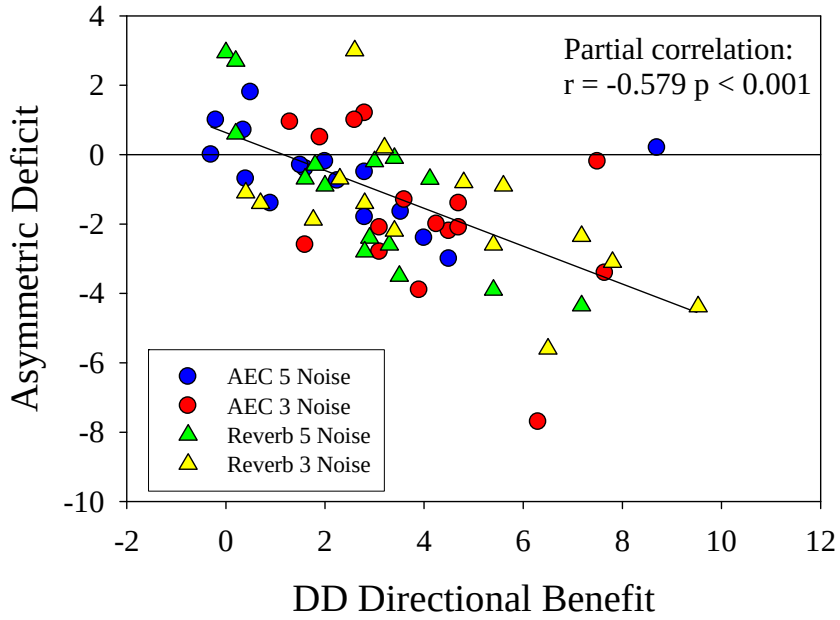

Figure B-17. Relationship between directional benefit in symmetric directional mode (D/D) and asymmetric deficit (change in directional benefit when switching to asymmetric mode (D/O) from symmetric directional mode). Symbols and colors reflect different rooms (anechoic or reverberant) and noise configurations [3 (back loaded condition) or 5 (Surround condition) noise loudspeakers]. Negative values reflect less directional benefit in asymmetric mode. Hornsby (2008).

Hornsby, B. and **Picou, E.** (August, 2008). Effect of hearing aid use on cognitive processing and listening effort in everyday settings. Poster presented at the International Hearing Aid Conference (IHCON), Lake Tahoe, CA.

Although poorer-than-normal speech understanding is common in many difficult listening situations, listeners with mild-to-moderate hearing loss often show essentially normal speech understanding in "easy" everyday listening conditions. Maintaining good speech understanding in these situations, however, may require allocation of more cognitive resources and more effortful listening for persons with hearing loss than for individuals without hearing loss (e.g. McCoy et al., 2005). In this poster we report preliminary results examining the effects of hearing aid use on cognitive processing, and indirectly, listening effort in everyday situations. Participants included 8 older adults with mild-moderate SNHL (48-75 years) and 10 younger adults with normal hearing (24-43 years). HI participants were fit with bilateral, open fit, Starkey Destiny 1600 BTE aids. Cognitive processing was tested three times during the day, to assess changes in cognitive demands and perceptual effort throughout the day using the MiniCog Rapid Assessment Battery (MRAB; Shephard and Kosslyn, 2005; Shephard et al., 2006). The MRAB consists of a battery of nine visual tests that assess various aspects of cognitive processing using measures of reaction time and accuracy. It was developed to allow individuals to rapidly assess cognitive processing in adverse environments (e.g., space, Antarctica, Mount Everest) using a handheld PDA. In addition, prior to each MRAB session, participants completed a 3 item questionnaire asking them to rate their recent listening effort and listening demands. Participants completed the MRAB three times/day (morning, afternoon and evening) for 1 (normal hearing) or 2 (HI) weeks. HI participants completed testing in both the unaided and aided conditions and the starting condition was counterbalanced. Participants also provided subjective ratings (on a scale of 0-10) of various aspects of listening effort prior to each MRAB test session.

Results showed significant differences in RTs, for all nine MRAB tests, between the younger NH group and the older HI group, in both the unaided and aided conditions were observed ($p < 0.001$, in all cases; see Figure B-18). However, there were no significant differences, on average, between hearing impaired participants in the unaided and aided conditions. Likewise, no significant effect of time of day was observed for any group. Subjective ratings data were limited to 5 participants due to various subject and experimenter errors. Due to the small sample size statistical analyses were not completed. An effect of time of day, if present, appears small in the current data. In addition, average results for questions 1 and 2 show a trend towards higher effort ratings in the unaided condition. In contrast, a reverse trend showing more effort in the aided condition is seen in responses to question 3 (See Figure B-19).
A preliminary analysis of associations between subjective effort ratings and MRAB test results (unaided and aided reaction times) were examined using the Spearman rank-order correlation coefficient. Results revealed significant correlations between effort ratings and unaided and/or aided absolute RTs (representative results from a single test are shown in the left panel of Figure B-20). Generally, participants with slower RTs had higher effort ratings. However, no significant relationship between change in RT and change in effort ratings were observed for any test (representative results from a single test are shown in the right panel of Figure B-z).

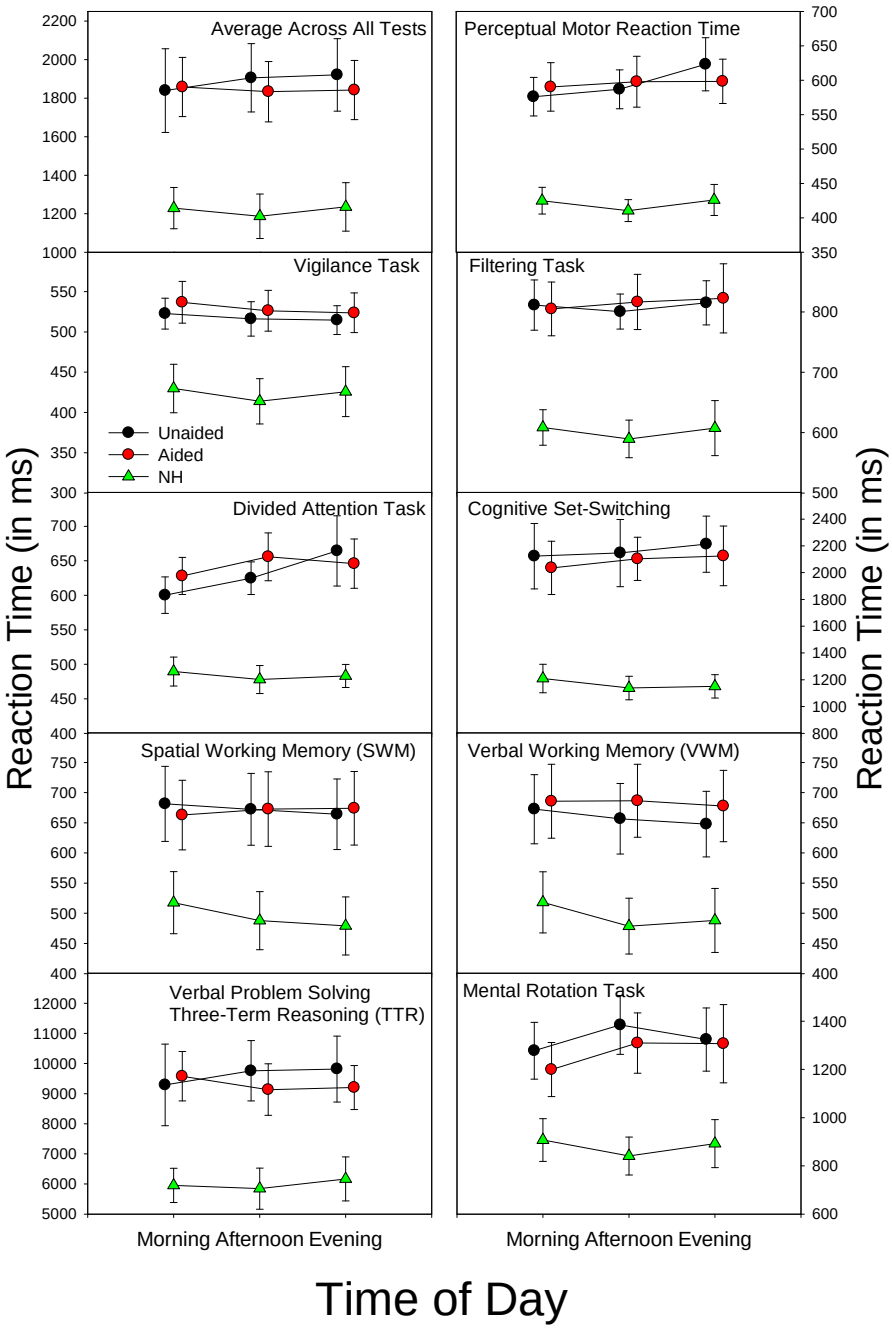

Figure B-18. Mean MRAB reaction time results (in ms) for both NH and HI (unaided and aided) groups as a function of time of day the test was taken. Average results across tests and individual test results are displayed. Error bars = 1 standard error. Results for the NH group are represented by green triangles, red and black circles represent aided and unaided HI results, respectively. Hornsby & Picou (2008).

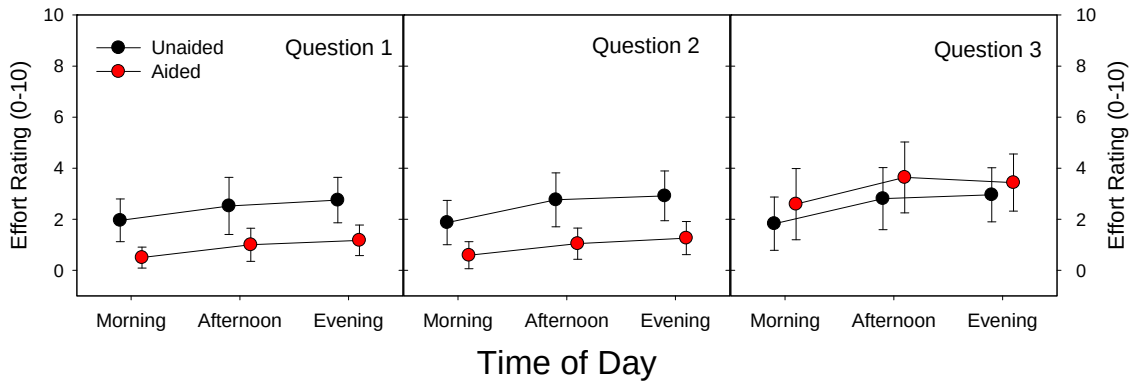

Figure B-19. Mean subjective ratings of ease of concentration (Q1), following conversation (Q2) and ignoring irrelevant sounds (Q3). Unaided and aided ratings are shown by the black and red circles respectively. Error bars = 1 standard error. Hornsby & Picou (2008).

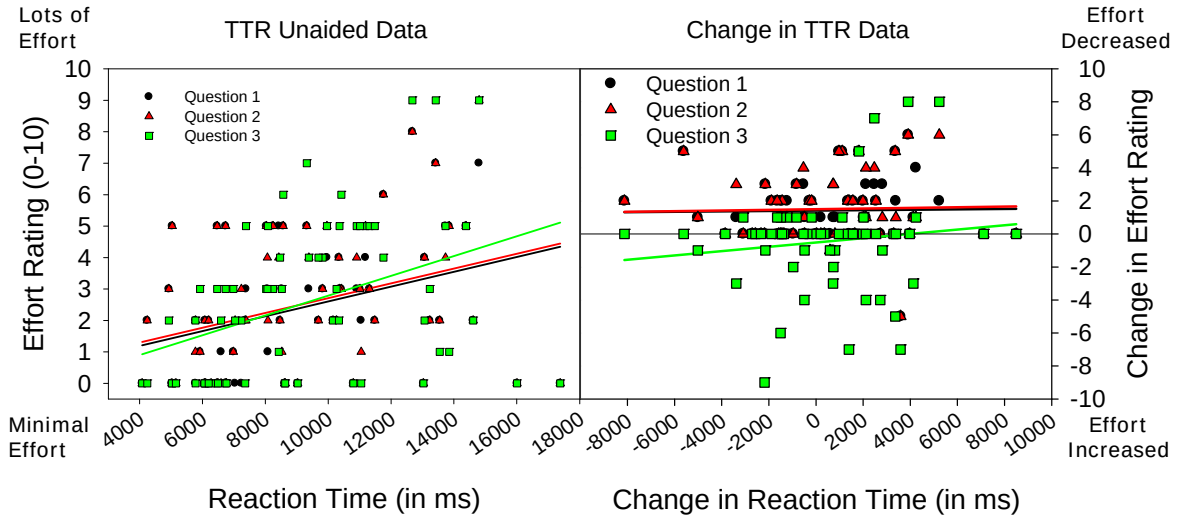

Figure B-20. An example of the relationship between Unaided effort ratings and reaction times (RT). Absolute effort ratings and RTs from TTR test (left panel) and Aided change in effort and change in TTR RTs (right panel). Hornsby & Picou (2008).

Johnson, E. E., **Ricketts, T. A.,** and **Hornsby, B. W. Y.** (2007). Effects of digital feedback reduction algorithms in modern digital hearing aids on sound quality. *Journal of the American Academy of Audiology*, 18(5), 404-416.

The effect of feedback reduction (FBR) systems on sound quality recorded from two commercially available hearing aids was evaluated using paired comparison judgments by 16 participants with mild to severe sloping hearing loss. These comparisons were made with the FBR systems on and off without audible feedback and while attempting to control for differences in gain and clinical fitting factors. Wilcoxon signed rank test analyses showed that the participants were unable to differentiate between signals that had been recorded with the FBR systems on and off within the same hearing aid. However,

significant between-instrument differences in sound quality were identified. The results support the activation of the FFT-phase cancellation FBR systems evaluated herein without concern for a noticeable degradation of sound quality.

Johnson, E. E., **Ricketts, T. A.,** and **Hornsby, B. W. Y.** (In Review). The effect of extending high-frequency bandwidth on the acceptable noise level (anl): An implication for hearing aid design. *International Journal of Audiology*.

This study examined the effects of extending high-frequency bandwidth, for both a speech signal and a background noise, on the acceptable signal-to-noise (SNR) of hearing impaired listeners through utilization of the Acceptable Noise Level (ANL) procedure. In addition to extending high-frequency bandwidth, the effects of other independent variables, which included room reverberation time and the background noise stimulus, were also examined. The study results showed a significant increase in the mean ANL of study participants (i.e., participants requested a better SNR for an acceptable listening situation) when high-frequency bandwidth was extended from 3 to 9 kHz and 6 to 9 kHz. No changes in participant-obtained mean ANLs were observed as result of isolated modification to reverberation time or the background noise stimulus. An additive interaction effect, however, of reverberation time and background noise stimulus was demonstrated. Main findings from this study suggest a hearing aid using extended high-frequency bandwidth through 9 kHz in the memory program designated for listening to speech in background noise is not optimal for the acceptance of background noise.

Piscopo, G.M. (2008). The effects of fire fighter safety attire and equipment on localization in the horizontal plane. Au.D. Capstone project completed under the direction of **W.W. Dickinson**, Vanderbilt University.

Background: Fire fighters utilize numerous, highly important skills during their missions in an attempt to save lives. Of these skills, the ability to detect and localize sound is imperative for a fire fighting mission to be successful as many lives are placed at risk. Currently, there is limited research regarding sound localization abilities in firefighters.
Purpose: The purpose of this project was to examine how horizontal sound localization was affected in normal hearing subjects while wearing full upper body safety attire and equipment. In addition, reaction time and subjective confidence ratings were examined.
Attire/Stimuli: Ten participants were tested individually in an anechoic chamber. They stood at the center of a 360° circular array of loudspeakers, whose radius was 2.0 m. There were two different attire conditions – bare head and full attire/equipment - and three different stimuli used – PASS Alarm, a female speaker yelling “help,” and a female speaker yelling “help, help,” resulting in a total of six conditions.
Procedure: Participants performed a source identification task under each of the six conditions. On each trial, the stimulus was presented from one of 16 source locations from the 360° array of loudspeakers, and the participant had to indicate which of the loudspeakers presented the stimulus.
Results: RMS error was significantly greater for the equipment-on condition than for the equipment-off condition for all three stimuli (see Figure B-21). In addition, more front-back and back-front errors were made with equipment on for both speech stimuli; however, more back-front errors were produced with the PASS alarm regardless of whether the equipment was on or off. Subjects were less confident in their responses with the equipment on versus equipment off. Reaction time ratings were inversely related to confidence ratings.
Discussion: Results suggest that fire fighter equipment significantly impacts a person’s ability to locate sound. Further research is needed to investigate the impact of individual components of the firefighter attire and equipment.

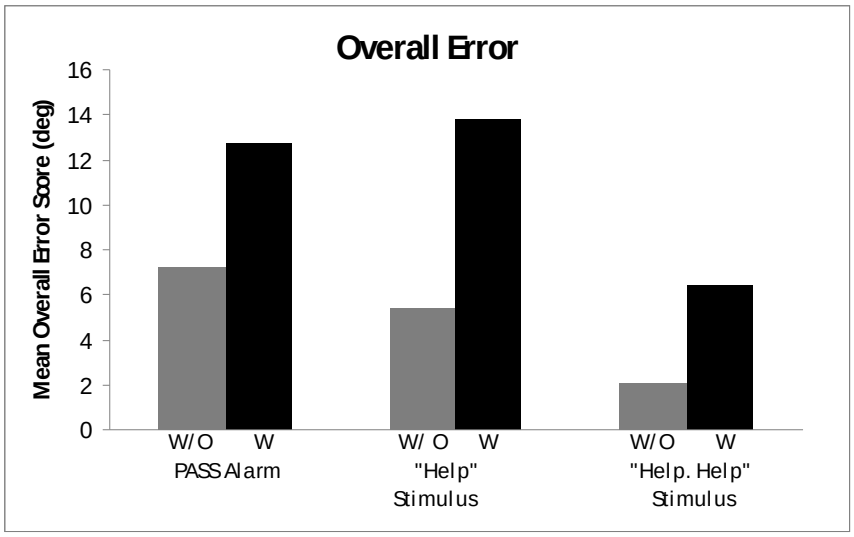

Figure B-21. RMS error score across all ten participants for the six conditions tested in the study. Black bars: performance with full equipment worn. Gray bars: performance with equipment not worn (bare head). Piscopo (2008).

Ricketts, T.A., **Galster, J.A.** and **Tharpe, A.M.** (2007). Directional benefit in simulated classroom environments. *American Journal of Audiology*,16(2), 130-144.

Several studies have shown that the use of hearing aids with directional microphones can lead to improved speech recognition in adult listeners in a variety of noisy listening environments. The purpose of the current experiments was to examine speech recognition performance and subjective ratings for directional and omnidirectional microphone modes across a variety of simulated classroom environments in a group of 26 children aged 10 to 17 years. In the first experiment five listening conditions were included that were intended to simulate common classroom conditions. These included: 1) “Teacher Front” which was intended to simulate a usual classroom with the teacher in the front of the room speaking and is similar to that experienced by a hearing impaired child with preferential seating; 2) “Teacher Back” which was identical to the first condition, except the speech loudspeaker was placed directly behind the participant at a distance of two meters; 3) “Desk Work” which was identical to the first listening condition; however, the participant was given a simple (1st grade level) math worksheet to complete and encouraged to “keep their eyes on their work”; 4) “Discussion” which was intended to simulate a roundtable discussion with three source loudspeakers placed 1.5 meters from the participants at 0˚ and +/- 50˚ azimuths; and, 5) “Bench Seating” which was intended to simulate listening to two talkers seated on either side of the participant as if seated on a bench. In school environments, this arrangement commonly occurs in cafeterias and gymnasiums, consisting of two source loudspeakers placed 0.55 meters from the participants at +/- 90˚ azimuths. The results from this experiment are shown in Figure B-22.

These results in combination with those from a second experiment involving other listening conditions and the results of a questionnaire provided after listening trials revealed significant directional benefit when the sound source(s) of interest was in front and directional decrement was measured when the sound source of interest was behind the participants. Of considerable interest, a directional decrement was observed in the absence of directional benefit when sources of interest were both in front and behind the participants (Experiment 2). Although these data support the use of

directional hearing aids in some noisy school environments they also suggest that use of the directional mode should be limited to situations in which all talkers of interest are located in the front hemisphere. In addition, limiting directional processing to the low frequencies eliminated both the directional deficit and the directional advantage (Experiment 3). These results highlight the importance of appropriate switching between microphone modes in the school- aged population. *Note: This article received the 2007 Editor's Award from the American Journal of Audiology.*

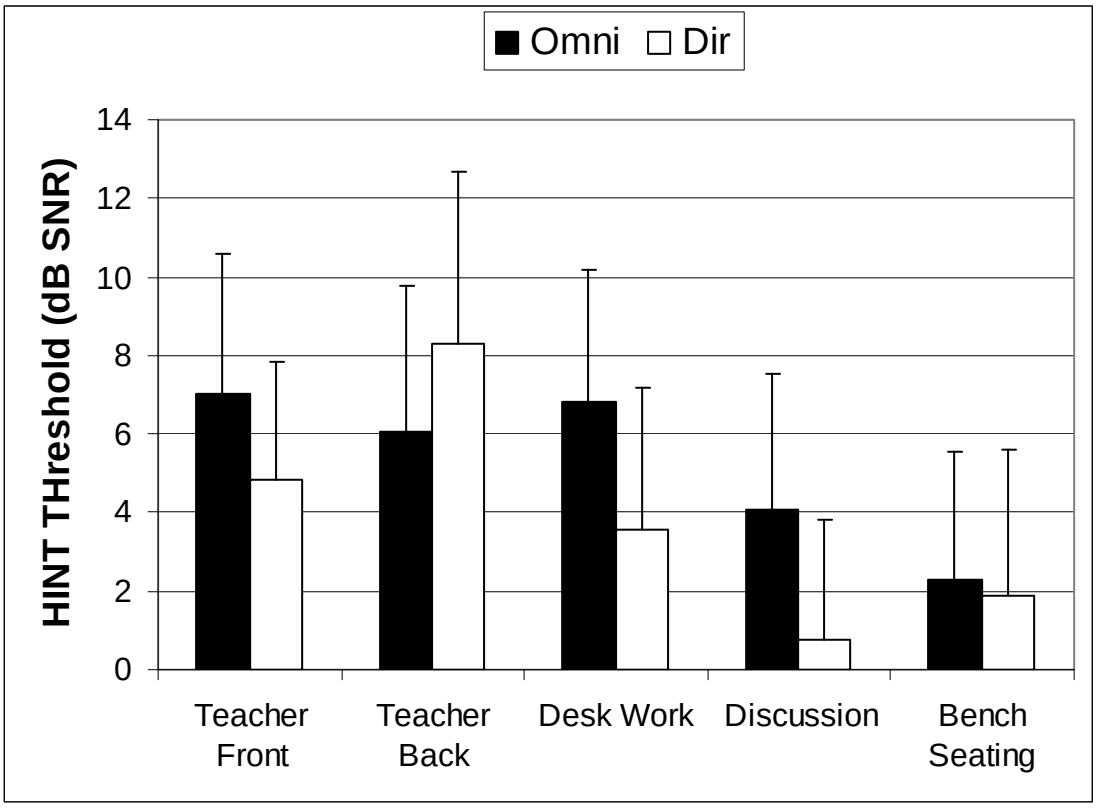

Figure B-22. The average speech recognition performance as measured by the HINT-C within the five simulated classroom conditions in each of the two microphone modes. The error bars represent one standard deviation. Ricketts *et al*. (2007).

Ricketts, T.A., Dittberner, A.B. and **Johnson, E.E.** (2008). High frequency amplification and sound quality in listeners with normal through moderate hearing loss. *Journal of Speech, Language and Hearing Research*, 51(1), 160-72.

One factor that has been shown to greatly affect sound quality is audible bandwidth. Extension of the high frequencies beyond 4-6 kHz has generally not been supported for groups of hearing aid wearers. The purpose of this study was to determine if preference for bandwidth extension in hearing aid processed sounds was related to the magnitude of hearing loss in individual listeners. The cut-off frequencies of 5.5 and 9 kHz were selected to represent bandwidths that are potentially achievable in modern hearing aids. Round-robin paired comparisons were made for two different monaurally presented brief sound segments including music and a movie. Results revealed that preference for either the wider or narrower bandwidth (9 or 5.5 kHz cut-off frequency, respectively) was not related to pure tone average hearing thresholds, or typical hearing loss groupings. Instead, preference appeared to be predictable from the slope of hearing loss from 4 to 12 kHz, with steep threshold slopes associated with preference for narrower bandwidths.

These data indicate a preference for wider bandwidths than are typically used in current commercial hearing aids in some listeners with hearing loss. This preference is important because it is possible that perceived poor sound quality resulting from limited bandwidth might be a factor contributing to the limited use of hearing aids by listeners with mild to moderate hearing loss.

Ricketts, T.A., and **Galster, J.A.** (2008). Head angle and elevation in classroom environments: implications for amplification. *Journal of Speech, Language and Hearing Research*, 51(2), 516-525.

There is considerable interest in attempts to improve speech recognition in noisy school environments using directivity- based microphone systems (e.g., directional hearing aids). However, the potential improvement gained by using such systems is highly dependent on the child's head orientation relative to the arrival angle of competing signals and the sound source of interest. Deviation in head angle and elevation relative to the direction of sound sources of interest were measured in 40 children, 4 to 17 years of age, with and without hearing loss in school environments. Deviation in head angle and elevation was tracked using three video cameras in real classroom environments every second over 20-60 minute time frame (see Figure B-23).

The results revealed similarly accurate head orientation across children with and without hearing loss, when focusing on the 33% proportion of time in which children were most accurate. Orientation accuracy was not affected by age. These results suggest that age is not an important factor when considering the potential for signal-to-noise improvements from directivity- based interventions in noisy environments. The data also revealed that children with hearing loss were significantly more likely to orient towards brief utterances made by secondary talkers than children with normal hearing. These data are consistent with the hypothesized association between hearing loss and increased visual monitoring.

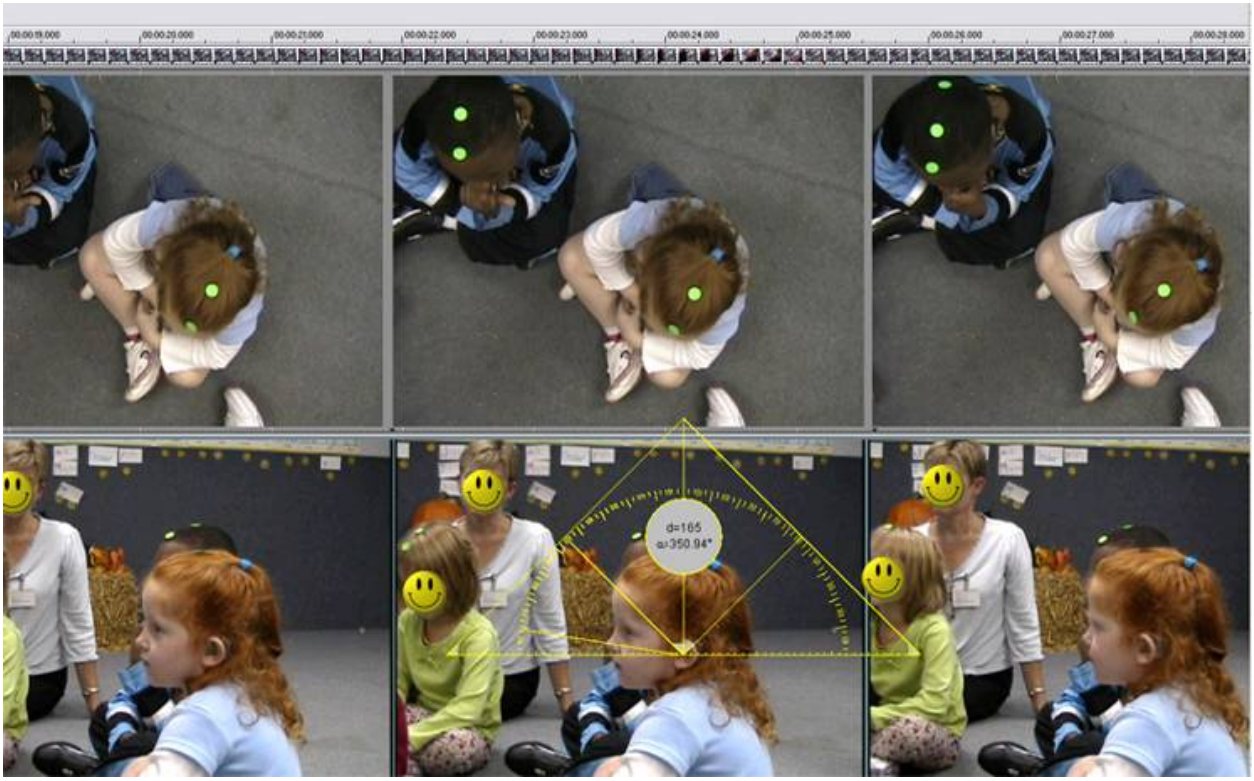

Figure B-23. An example of a single frame measurement of head angle and elevation. Ricketts & Galster (2008).

Ricketts, T.A., Johnson, E.E., and **Federman, J.** (2008). Individual differences within and across feedback suppression hearing aids. *Journal of the American Academy of Audiology*, 19.

New and improved methods of feedback suppression are routinely introduced in hearing aids, however, comparisons of additional gain before feedback (AGBF) values across instruments are complicated by potential variability across subjects and measurement methods. The purpose of this study was to examine the variability in AGBF values across individual listeners and an acoustic manikin using a descriptive study of the reliability and variability of the AGBF measured within six commercially available feedback suppression (FS) algorithms using probe microphone techniques. Sixteen participants and an acoustic manikin were evaluated in this study.

The results of this study revealed the range of AGBF across the six FS algorithms was 0 to 15 dB, consistent with other recent studies. However, measures made in the participants ears and on the acoustic manikin within the same instrument suggest that across instrument comparisons of AGBF measured using acoustic manikin techniques may be misleading, especially when differences between hearing aids are small (i.e. less than 6 dB). Individual subject results also revealed considerable variability within the same FS algorithms. The range of AGBF values was as small as 7 dB and as large as 16 dB depending on the specific FS algorithm, suggesting that some models are much more robust than others. These results suggest caution when selecting FS algorithms clinically since different models can demonstrate similar AGBF when averaging across ears, but result in quite different AGBF values in a single individual ear.

Ryan, H. A. M., **Tharpe, A. M.**, and **Ashmead, D. H.** (March, 2008). Visual attention in deaf, unilaterally hearing-impaired and hearing adults. Poster session presented at the 2008 Meeting of the American Auditory Society, Scottsdale, AZ.

It is well known that early deficits in one sensory system can influence changes in another sensory system. The Eriksen Flanker Task was used to measure the visual attention abilities of normal hearing (NH), unilaterally hearing-impaired (UHL), and Deaf adults. Participants viewed a centrally-located target letter flanked by same (compatible) or different (incompatible) letters on a computer monitor. The letters *N* and *H* served as both targets and flankers. Flankers were spaced at varying degrees of eccentricity from the target. Participants quickly pressed a button to indicate if the target was *H* or *N* and reaction times were recorded. Typically, reaction times are longer in incompatible conditions and when incompatible flankers have a small degree of separation from the target. This lengthening of the reaction times because of flankers influence is known as the flanker compatibility effect. Both the UHL and Deaf groups demonstrated a flanker compatibility effect at farther eccentricities than did the NH group. These results were discussed in terms of possible contributing experimental factors.

Spankovich, C., **Hood L.J.**, Silver, H., Lambert, W., Flood, V., and Mitchell, P. (In preparation.) Dietary intake and susceptibility to hearing loss and tinnitus.

Hearing loss is a condition encompassing a composite of etiologies expounded by risk factors including, but not exclusive to genetics, age, sex, noise exposure, disease, and ototoxic compounds. An important, but seemingly neglected factor that may influence susceptibility to hearing loss is dietary intake. While recent studies have investigated the relationship between some specific dietary variables (predominantly antioxidants in the form of supplements and pharmaceutical agents); no study has provided a general epidemiological exploration of macro- and micro- nutrients and associations with auditory outcome measures. The present study explored associations between dietary intake variables and hearing loss in a population of older adults. In particular, nutrients that are rich in antioxidants (vitamins), increase availability of antioxidants (vitamins, minerals, and

protein), and effect blood flow (fats and minerals) were of interest. The findings support the literature, reveal novel associations, and substantiate dietary intake as a relevant factor for susceptibility to hearing loss. An argument is provided that emphasizes the importance of nutrient homeostasis and discusses potentials and limitations of dietary variables in susceptibility to hearing loss.

Stach, B.A., **Hornsby, B.**, **Rosenfeld, M.**, and De Chicchis, A. (In press). The complexity of auditory aging. *Seminars in Hearing*.

Age-related decline in hearing is the result of complex changes in audibility, suprathreshold processing, and cognition. Changes in cochlear structures, whether from biologic aging of the structures themselves or secondary to intrinsic and extrinsic influences that occur with the passage of time, result in hearing sensitivity loss. The outward expression of the underlying disorder is fairly consistent. That is, loss of function of cochlear hair cells and other structures consistently manifest hearing sensitivity loss and the consequent deficits in audibility. Age-related changes in auditory nervous system structures may also play a role in overall hearing capability, although the outward expression of the disorder is likely to be subtler than cochlear loss in a given individual and considerably more variable among individuals. Regardless, the complex hearing disorder associated with the aging process can have a significant impact on overall wellness. This review article provides an overview of aging and age-related decline in audition, with an emphasis on speech perceptual deficits with aging.

C. Speech and Language Science — Applied

Abou-Khalil, R. and **Schneider, S.L.** (May, 2009). **A** new treatment for aphasia? Borrowing from the field of foreign language learning. Poster to be presented at the Clinical Aphasiology Conference, Keystone, CO.

There is a substantial literature examining the 'holistic' approach to the treatment of aphasia, in which right hemisphere mediation is presumably invoked. From the field of foreign language education, a new method of teaching has emerged which relies on a holistic approach to language acquisition, as opposed to the analytical traditional approach. This method, called Total Physical Response (TPR), lends itself to aphasia treatment. During recovery from a left hemisphere stroke, it is important to recruit the intact right hemisphere which may aid neural reorganization and support language recovery. The TPR methodology recruits both hemispheres equally. Therefore, it is reasonable to apply TPR principles to the treatment of aphasia.

Arnold, H., Conture, E., Key, A. and Walden, T. (Submitted). Emotional reactivity, regulation and childhood stuttering: A behavioral, electrophysiological study.

Purpose: The purpose of this study was to assess whether behavioral and psychophysiological correlates of emotional reactivity and regulation are associated with developmental stuttering.
Method: Nine preschool-age children who stutter (CWS) and nine preschool-age children who do not stutter (CWNS) listened to brief background conversations conveying happy, neutral, and angry emotions (a resolution conversation followed the angry conversation) and then produced narratives based on a text-free storybook. Electroencephalograms (EEG) were recorded during the listening part to examine cortical correlates of emotional reactivity and regulation. Speech disfluencies and observed emotion regulation were measured during the subsequent narratives.
Results: Results revealed no significant differences between CWS and CWNS in EEG measurements of emotional reactivity and regulation during background conversations designed to elicit emotions. However, behavioral findings indicate that preschool-age CWS, compared to CWNS, were less adept at emotion regulation and that the tendency to regulate less was related to increased speech disfluency.
Conclusions: Findings were taken to suggest that emotion regulation is one important contributor to the difficulties some children have establishing and maintaining normally fluent speech-language production.
Research supported in part by NIH/NIDCD research grant 1R01DC0006477-01AS.

Arnold, H., Ntourou, K., and **Conture, E.G.** (2007, November). Relations of emotional reactivity and regulation to attitudes about talking in preschool children who stutter. Poster presented at the annual ASHA Convention, Boston, MA.

This study examined relations between the emotional reactivity and regulation of young children who stutter (CWS) and their attitudes about talking. Participants were 48 3- to 6- year old CWS who completed a self-report measure of communication attitudes, the Kiddy-CAT (Vanryckeghem & Brutten, 2006) and whose parents completed a measure of emotional reactivity and regulation, the Children's Behavior Questionnaire (Rothbart, Ahadi, Hershey, & Fisher, 2001). Results indicate that attitudes toward talking were unrelated to emotional reactivity and regulation (ERR) in preschool CWS suggesting that these attitudes may involve more conscious, cognitive recollections of the child's personal experiences while ERR may involve the child's more unconscious, emotional responses to his or her external and internal environment. Worked supported in part by NIH/NIDCD research grant 1 R01EC006477-01A2.

Buhr, A., and **Conture, E.** (November, 2008). Loci of early childhood stuttering and procedural memory: Preliminary findings. Poster presented at the Annual Conference of the American Speech Language and Hearing Association, Chicago.

The purpose of this study was to assess whether speech-language variables related to declarative and procedural memory contribute to the loci of developmental stuttering (i.e., word class and/or sentence position). Participants were 24 preschool-age CWS. Loci measures were obtained from parent-child conversational samples and standardized measures of speech-language abilities. Results indicated that stuttering on function words was positively related to PPVT-EVT differences, suggesting that at least some preschoolares who stutter may possess a subtle deficit in procedural and/or an over-reliance on declarative memory. Research supported in part by NIH/NIDCD research grants 5R01DC000523-14 and 1R01DC006477-01A2.

Buhr, A., and **Conture, E.** (November, 2008). Vagal tone and sustained attention in adults who stutter. Poster presented at the Annual Conference of the American Speech Language and Hearing Association, Chicago.

The present study examined the ability to regulate attention as a possible contributor to stuttering. Four adults who stuttered (AWS) and four adults who did not stutter (AWNS) had their ECG signals recorded during three tasks: passively viewing a film clip, reading rapidly-scrolling text, and responding during a Go/NoGo task. Attention regulation was defined as the ability to release vagal influence on the heart, as indexed by increases in sympathetic-vagal balance (SVB). Results indicated that from viewing the film to reading the text, SVB increased for 25% of AWNS and 50% of AWS. On the Go/NoGo task, AWNS exhibited faster response times (455 ms) than AWS (611 ms), with RTs being negatively related to SVB. Results suggest that AWS utilize relatively more resources for attention regulation, which, during speaking, may lead to communicative performance decrements in some adults who stutter. Worked supported in part by NIH/NIDCD research grant 1 R01EC006477-01A2.

Buhr, A. P., Conture, E. G., and **Ntrourou, K.** (April, 2008), Effects of word class, sentence position, and sentence complexity on stuttering in preschool children. Poster presented at the annual Human Development Conference, Indianapolis, IN.

The purpose of this study was to assess how stuttering in preschool children is influenced by word class, sentence position, and sentence complexity. Participants included 24 preschool children who stutter between the ages of 3;0 and 5;11. Measures of sentence position, word class, and MLU in relation to stuttering were obtained from transcriptions of spontaneous speech. Results showed that participants tended to stutter on function words at the sentence-initial position, and that this tendency was greatly influenced by sentence complexity. Findings were taken to suggest that difficulties with syntactic planning, particularly at longer, more complex sentences, contribute to childhood stuttering. Research supported in part by NIH/NIDCD research grant 5R01DC000523-14 and NIH training grant T32HD07226.

Buhr, A. P., Ntourou, K., and **Conture, E.G.** (2008, April). Loci of early childhood stuttering and procedural memory: Preliminary findings. Poster presented at the International Fluency Symposium, Antwerp, Belgium.

The purpose of this study was to assess whether speech-language variables related to declarative and procedural memory contribute to the loci of developmental stuttering (i.e., word class and/or sentence

position). Participants were 24 male preschool-age children divided into three age groups (8/age group): 3-year-olds (3;0-3;6), 4-year-olds (4;0-4;6), and 5-year-olds (5;0-5;6). Loci measures were obtained from parent-child conversational samples and speech-language measures based on standardized vocabulary recognition (PPVT) and retrieval (EVT) tests. Results indicated that stuttering on sentence-initial words was positively related to PPVT-EVT differences, suggesting that at least some preschoolers who stutter may possess a subtle deficit in procedural memory and/or an over-reliance on declarative memory. Research supported in part by NIH/NIDCD research grant 5R01DC000523-14 and NIH training grant T32HD07226.

Buhr, A. P., and Zebrowski, P. M. (October, 2007). The influence of word class on the loci of stuttering in children: A longitudinal study. Poster presented at the annual Tennessee Association of Audiology and Speech-Language Pathology Conference, Chattanooga, TN.

The purpose of this presentation was to empirically study the relationship between stuttering on function versus content words and persistence of developmental stuttering. Parent-child conversational samples were gathered from 12 preschool children over five visits at six-month intervals. Participants were four non-stuttering children (mean age: 48 months at Visit I), four children who recovered (mean age: 50 months at Visit I), and four children who persisted (mean age: 49 months at Visit I). Conversational samples were recorded and transcribed, from which stuttering and word class measurements were made. Results indicated that persistent children were more likely to stutter on words at the initial position of sentences, the position where function words were shown to be most frequent for all children. Findings were taken to suggest that persistent children may have more difficulty planning or initiating utterances than children who recover from stuttering or children who do not stutter. Research supported in part by NIH/NICDC research grants RO1DC05210 and NIH training grant T32HD07226.

Buhr, A. B., and Zebrowski, P. M. (Submitted). Word and sentence-based measures of stuttering in early childhood: A longitudinal study.

The purpose the present investigation was to longitudinally assess word and sentence-based measures of stuttering in young children. Participants included 12 preschool children who exhibited a range of stuttering frequencies. Parent-child spontaneous speech samples were obtained over a period of two years at six-month intervals. Each speech sample was transcribed, and both stuttering-like disfluencies (SLDs) and other disfluencies (ODs) were coded. Word and sentence-based measures of SLDs were used to assess potential linguistic contributions to stuttering. Results showed that SLDs and ODs were most likely to occur at the beginning of sentences, and sentences containing SLDs and those containing ODs were significantly longer and more complex than fluent sentences, but not significantly different from each other. Results were taken to suggest that both SLDs and ODs originate during the same stage of sentence planning. Research supported in part by NIH/NICDC research grants RO1DC05210 and NIH training grant T32HD07226.

Buhr, A. P., Zebrowski, P.M., and Moon, J. B. (April, 2008). Jaw movement of young children who stutter as a function of linguistic complexity. Poster presented at the annual Human Development Conference, Indianapolis, IN.

The development of speech-motor skills relative to linguistic complexity was examined as a potential factor in early childhood stuttering. Participants included five preschool children who stuttered and five who did not stutter. Mean amplitude, duration, and peak velocity of opening and closing jaw gestures of bilabial stop consonants were measured across four levels of linguistic complexity. Results showed that

mean duration of the opening gesture was significantly longer for children who stuttered, but this effect did not interact with linguistic complexity. It was concluded that children who stutter take longer to initiate speech, independent of linguistic. Research supported in part by NIH/NICDC research grant RO1DC05210 and NIH training grant T32HD07226.

Byrd, C., **Conture, E.**, and **Ohde, R.** (2007). Incremental and holistic phonological priming of young children who stutter. *American Journal of Speech-Language Pathology*, 16, 43-53.

Purpose: To investigate the holistic versus incremental phonological encoding processes of young children who stutter (CWS; N = 26) and age- and gender-matched children who do not stutter (CWNS; N = 26) via a picture-naming auditory priming paradigm.
Method: Children named pictures during 3 auditory priming conditions: neutral, holistic, and incremental. Speech reaction time (SRT) was measured from the onset of picture presentation to the onset of participant response.
Results: CWNS shifted from being significantly faster in the holistic priming condition to being significantly faster in the incremental priming condition from 3 to 5 years of age. In contrast, the majority of 3- and 5-year-old CWS continued to exhibit faster SRT in the holistic than the incremental condition.
Conclusion: CWS are delayed in making the developmental shift in phonological encoding from holistic to incremental processing, a delay that may contribute to their difficulties establishing fluent speech. Research supported in part by NIH/NIDCD research grant 5R01DC000523-14.

Camarata, S. (In press). FastForward does not significantly improve language skills in children with language disorders. *Evidenced Based Practice in Communication Disorders*.

The study was well constructed and rigorously conducted randomized clinical trial with low attrition and a high degree of internal and external validity. The results are not consistent with the temporal auditory processing deficit hypothesis for treating language disorders. This is an important finding because the auditory processing deficit hypothesis is a primary theoretical underpinning for a number of auditory processing intervention programs such as FFW and EarRobics (the latter was included in the CALI condition), yet these approaches were no better than individualized instruction or general enrichment for improving receptive and expressive language.

The results of this study cast doubt on the value of auditory processing training programs, such as FastForWard, for improving language skills over and above that achieved through individual language intervention and academic enrichment. It remains an open question whether interventions based on auditory processing training will significantly improve language abilities as compared to maturation and generic school based language exposure and supports because a non-active treatment comparison group is needed to address this later question.

Camarata, S., Nelson, K., Gillum, H., and **Camarata, M.** (In press). Incidental Receptive Language Growth Associated with Expressive Grammar Intervention in SLI. *First Language.*

Children with SLI (Specific Language Impairment) display language deficits in the absence of frank neurological lesions, global cognitive deficits or significant clinical hearing loss. Although these children can display disruptions in both receptive and expressive grammar, the intervention literature has been largely focused on expressive deficits. Thus, there are numerous reports in the literature suggesting that expressive language skills can be improved using focused presentation of grammatical targets (cf. conversational recast; Camarata, Nelson & Camarata, 1994), but there have been few investigations addressing the remediation of receptive language skills in SLI for those children with receptive language

deficits. The purpose of this study was to examine whether focused grammatical intervention on expressive grammar is associated with growth in receptive language in 21 children with SLI who have receptive language deficits. These children displayed significant growth in receptive language scores as an incidental or secondary association with expressive language intervention and significantly higher gains than seen in a comparison-control group with SLI and receptive language deficits (*n* = 6). The theoretical and clinical implications of these results are discussed.

Coalson, G.A., Karrass, J., Walden, T.A., and **Conture, E.G.** (November, 2007). Parental stress interaction with childhood stuttering. Poster presented at the annual ASHA Convention, Boston, MA.

Relations between parental stress and developmental stuttering were assessed in parents of 46 preschool children who stutter (CWS) and 41 children who do not stutter (CWNS). Parents reported on their parenting and general stress. Contrary to expectations, parents of CWS and CWNS reported similar stress levels, and parental stress did not correlate with stuttering frequency, severity, or time since onset. Furthermore, relations between CWS age and parental stress were not statistically significant, as they were in CWNS, suggesting that characteristics of the stuttering child maintain higher levels of parental stress. Research supported in part by a Discovery grant from Vanderbilt University.

Conture, E. (April, 2008). Dual Diathesis-stressor model of childhood stuttering. Invited presentation to European Symposium Fluency Disorders, Antwerp, Belgium.

For the approximately 1% of children who continue to stutter after 6 years of age, the negative impact of stuttering can be significant in terms of academic, emotional, social, vocational achievement, development and potential. Thus, there is a need to determine which variables may initiate/cause, exacerbate or perpetuate stuttering to eventually develop more efficient, effective data-motivated approaches to diagnosis and treatment. Trying to address that need, the presenter has pursued a program of empirical study of speech-language planning and production as well as dispositional and situational aspects of emotions in attempts to determine whether these variables may be causal contributors to developmental stuttering. Based on a relatively large data-base (n = 300) involving preschool children who do and do not stutter, findings from select descriptive as well as experimental investigations will be presented. These findings will be used to support a dual diathesis-stressor model of developmental stuttering. Specifically, subtle, probably developmental, inefficiencies in speech-language planning production (vulnerability or diathesis 1) and/or lowered threshold of reactivity to change, difference or novelty (diathesis 2) are thought to be present for at least some children who stutter. These diatheses are believed to be exacerbated by the degree to which speech-language is generated spontaneously or on-the-fly (stressor 1) and/or the degree to which change, difference or novelty occurs in the environment (stressor2). Because the nature and number of interactions between these causal contributors is probably unevenly distributed across the population of children who stutter, it seems reasonable to suggest that no one size (explanation) will fit all children who stutter. Research supported in part by NIH/NIDCD research grants 5R01DC000523-14 and 1R01DC006477-01A2.

Coulter, C. E., **Conture, E. G.** and Anderson, J.D. (Submitted). Childhood stuttering and dissociations across linguistic domains: A replication and extension.

The purpose of this investigation was to replicate Anderson, Pellowski, and Conture's (2005) findings that young preschool children who stutter (CWS) are more likely to exhibit dissociations in speech-language abilities than children who do not stutter (CWNS) (Study 1) and to examine the relation between these dissociations and specific characteristics of stuttering (e.g., most common disfluency type) (Study

2). Participants for Study 1 were 40 CWS and 40 CWNS between the ages of 3;0 and 5;11 matched for age, gender, and race. Participants for Study 2 were the same as for Study 1 plus the 90 used by Anderson et al (2005) for a total of 170 participants, matched for age, gender and race.. Participants were administered four standardized speech-language tests and a 300-word conversational speech sample was obtained from each participant during a play-based interaction with an adult. Standard scores, obtained from these four standardized speech-language tests, were analyzed by a correlation-based statistical procedure (Bates, Applebaum, Salcedo, Saygin & Pizzamiglio, 2003) in attempts to identify possible dissociations among the speech-language measures. Findings from the current investigation supported Anderson et al.'s (2005) findings that CWS exhibited significantly more speech-language dissociations than CWNS. Results indicated that the degree of dissociation was significantly, positively correlated with frequency of total as well as stuttering-like disfluencies. Furthermore, CWS who exhibited dissociations were significantly more likely to exhibit interjections or revisions as their most common disfluency type. Findings provide further support for the possibility that dissociations among various aspects of the speech-language system may contribute to the difficulties that some children have establishing normally fluent speech. Research supported in part by NIH/NIDCD research grant 5R01DC000523-14.

de Riesthal, M. (2007). Training specific treatment techniques: Next step in evidence-based practice? *Journal of Medical Speech Language Pathology, 15(1),* p. xi-xiv.

This article discusses the need for improved training of specific treatment techniques to ensure clinicians' fidelity to treatment protocols and maximize the desired treatment effects. Potential methods for achieving this goal are discussed.

Golper, L. et al. (November, 2008). Leadership skills for managing professional transitions. Division 11, 4-hour pre-conference Course, ASHA Convention, Chicago.

This four-hour special, preconference short course is sponsored by ASHA's Division 11, Administration and Supervision. The course addresses the management of transitions in professional development with presentations from invited presenters; topics and presenters include: 1) transitions from student to clinical fellow (Bartlett); 2) transitions from the clinical fellowship to a staff position (Hudson); 3) the transition from jurnior to senior staff (Vega Barachowitz); 4) transition from staff positions to management positions (Golper); and 5) transition to leadership in professional service organizations (Johnson).

Golper, L. et al. (November, 2007). What employers want: a vision for the future of medical SLP and early intervention. Presented at NSSLHA Day, ASHA Convention, Boston, MA.

This invited session reviews for students entering the profession of audiology and speech-language pathology the essential qualities employers are seeking in entry level staff. Three presenters discussed this topic from the perspective of: public schools (Homer), early intervention and medical settings (Golper) and a systems analysis of expectations across settings (Rudebush).

Johnson, K., **Conture, E.**, Walden, T., and Karrass, J. (November, 2008). Attention regulation in preschool children who stutter. Poster presented at the Annual Conference of the American Speech Language and Hearing Association, Chicago.

This study assessed the attentional processes of preschool children who do (CWS) and do not stutter (CWNS) during a traditional cueing task and an affect cueing task. Participants were preschool-age CWS

and CWNS (age- and gender-matched). Preliminary findings indicate no difference in reaction time (RT) or overall errors, but a between-group difference in error-type. Also, for CWNS, increased errors correlated with increased (slower) RT, but not for CWS. Findings suggest less efficient regulation of attentional processes in CWS when compared to CWNS. Research supported in part by NIH/NIDCD research grant 1R01DC0006477-01AS.

Johnson, K. N., Karrass, J., **Conture, E. G.**, and Walden, T. (In press). Influence of stuttering variation on talker group classification in preschool children: Preliminary findings. *Journal of Communication Disorders.*

The purpose of this study was to investigate whether variations in disfluencies of young children who do (CWS) and do not stutter (CWNS) significantly change their talker group classification or diagnosis from stutterer to nonstutterer, and vice versa. Participants consisted of 17 3- to 5-year-old CWS and 9 3- to 5-year-old CWNS, with no statistically significant between-group difference in chronological age (CWS: M = 45.53 months, SD = 8.32; CWNS: M = 47.67 months, SD = 6.69). All participants had speech, language, and hearing development within normal limits, with the exception of stuttering for CWS. Both talker groups participated in a series of speaking samples that varied by: (a) conversational partner [parent and clinician], (b) location [home and clinic], and (c) context [conversation and narrative]. The primary dependent measures for this study were the number of stuttering-like disfluencies (SLD) per total number of spoken words [%SLD] and the ratio of SLD to total disfluences (TD) [SLD/TD]. Results indicated that variability of stuttering did not exist as a result of conversational partner or location. Changes in context, however, did impact the CWS, who demonstrated higher SLD/TD in the conversation sample versus a narrative sample. However, consistent with hypotheses, CWS and CWNS were accurately identified as stutterers and nonstutterers, respectively, regardless of changes to conversational partner, location or context for the overall participant sample. Potential implications of present findings, relative to assessments, suggest that although differences in the frequency of stuttering may vary as a result of conversational partner, location or context, such variation does not significantly influence or change whether a child who stutters is accurately identified as a stutterer based on in-clinic samples alone. Research supported in part by NIH/NIDCD research grant 5R01DC000523-14 and a Discovery grant from Vanderbilt University.

Johnson, K. N., Walden, T., **Conture, E. G.**, and Karrass, J. (Submitted). Spontaneous regulation of positive and negative emotionality in preschool children who stutter: Preliminary findings.

The purpose of this study was to assess the emotional regulation of preschool children who do (CWS) and do not stutter (CWNS) in a social (i.e., with gift-giver present) context using a disappointing gift procedure. Participants consisted of sixteen 3- to 5- year-old CWS and the same number of CWNS with no statistically significant between-group differences in chronological age between the talker groups (CWS/ CWNS). All participants had speech, language, and hearing development within normal limits, with the exception of stuttering for the CWS. After assessment of each child's display rule knowledge, the child participated in a disappointing gift (DG) procedure where they received a desirable gift preceding a conversational speaking task and a disappointing gift preceding a second, similar conversational speaking task. During the DG procedure, the experimenter measured each participant's positive and negative expressive nonverbal behaviors exhibited during receipt of (1) a desirable gift and (2) a disappointing gift as well as their conversational speech disfluencies exhibited following receipt of (3) a desirable gift and (4) a disappointing gift. Findings indicate that, although CWS and CWNS have knowledge of display rules and exhibit an equal amount of positive expression after receiving a desired gift, behaviorally, CWS, are more apt to exhibit negative expression after receiving a negative gift. Furthermore, relative to stuttering, CWS tend to be more disfluent after receiving a desired gift when

compared to receiving a disappointing gift. Findings were taken to suggest that the use of emotional regulatory behavior might contribute to childhood stuttering, particularly in situations involving positive emotions. Research supported in part by NIH/NIDCD research grant 1R01DC0006477-01A2 and a Discovery grant from Vanderbilt University.

Johnson, K. N., and **Conture, E. G.** (November, 2007). A behavioral study of attention regulation in preschool children who stutter. Poster presented at the annual ASHA convention, Boston, MA.

The purpose of this study was to assess the attentional processes of preschool children who do (CWS) and do not stutter (CWNS) during a traditional cueing task and an affect cueing task. Participants consisted of twelve 3- to 5-year-old CWS and the same number of CWNS. Both talker groups participated in two tasks: (1) traditional cueing and (b) affect cueing. During both cueing tasks participants focused on a fixation point ("cookie monster face") and provided non-speech motor responses (i.e., button pressing) to computer-presented target stimuli ("cookie"). Each target was preceded by visual cues (i.e., highlighted box) occurring in either the same right or left location as the target stimuli (i.e., valid trials) or in the opposite location of the target (i.e., invalid trials). The affect cueing task was preceded by stress-heightening instructions intended to influence participants' emotionality. Reaction times (RT) were measured (in milliseconds) from the onset of presentation of the target stimuli ("cookie") to the onset of the participant's non-speech motor response (i.e., button pushing) during both the traditional cueing and the affect cueing tasks. Results indicated that although there were no significant between-group differences in RT or frequency of erroneous responses, CWS and CWNS differed in type of errors exhibited during both tasks. Additionally, the validity difference of CWS and CWNS was significantly influenced by the introduction of stress-heightening instructions. Findings were taken to suggest that for the present task, speed of attentional disengaging, shifting and re-engaging did not differ between CWS and CWNS, but that the nature of CWS errors was influenced by the affect-stimulating condition. This latter finding suggests that if during situations of heightened arousal/emotionality CWS must quickly shift and re-engage their attention to respond correctly, they may have difficulty with attentional disengagement that is, being able to be distracted in order to orient one's attention appropriately. Research supported in part by NIH/NIDCD research grant 1R01DC0006477-01A2. and a Discovery grant from Vanderbilt University.

Johnson, K. N., Karrass, J., Walden, T. A., and **Conture, E. G.** (April, 2008). Regulation of negative emotionality in preschool children who stutter: Maternal self-report vs. behavioral observations. Poster presented at the annual Human Development Conference, Indianapolis, IN.

The purpose of this study was to assess the emotional regulation of preschool children who do (CWS) and do not stutter (CWNS) and their mothers' responses to displays of emotion through (1) behavioral observation using a disappointing gift (DG) procedure and (2) maternal self-report of how they cope with their child's negative emotionality (Coping With Children's Negative Emotions Scale- CCNES). Participants were fourteen 3- to 5- year-old CWS and 14 CWNS and their respective parent(s). Prior to behavioral observation, each mother completed the CCNES. Then each child participated in a DG procedure where they received a desirable gift preceding a play-oriented parent-child conversational task with their mother and a disappointing gift preceding a second, similar conversational task. Results indicated that behavioral observations of negative emotion were more strongly correlated to maternal report for CWS than CWNS. Findings were taken to suggest that for CWS, maternal behaviors may be driving aspects of the child's emotional responses during negative situations or vice versa. Research supported in part by NIH/NIDCD research grant 1R01DC0006477-01A2 and a Discovery grant from Vanderbilt University.

Johnson, K. N., Karrass, J., Walden, T., and **Conture, E. G.** (April, 2008). Spontaneous regulation of negative emotionality in preschool children who stutter. Poster presented at the National Black Association for Speech Language and Hearing, Washington, DC.

This study assessed the emotional regulation (ER) of preschool children who do (CWS) and do not stutter (CWNS) using a disappointing gift (DG) procedure. Positive and negative expressive behaviors as well as disfluencies were coded during (expressive behaviors) and after (disfluencies) receipt of a desirable gift and a disappointing gift. Findings indicate that CWS exhibit less positive expression after receiving a desired gift and more negative expression after receiving a negative gift when compared to CWNS. Additionally, CWS are more disfluent after receiving a desired gift. Findings suggest that ER may contribute to childhood stuttering, particularly in positive emotional situations. Research supported in part by NIH/NIDCD research grant 1R01DC0006477-01A2 and a Discovery grant from Vanderbilt University.

Johnson, K. N., and Robinson, Jr., T. L. (March, 2008). Stuttering assessments in preschoolers: From lab to clinic. Mini-seminar presented at the National Black Association of Speech Language and Hearing, Washington, DC.

This mini-seminar is Part I of a two-part seminar on the fundamental aspects necessary to conduct comprehensive evidence-based assessments of stuttering in the preschool population. Specifically, during Part I, empirical findings linking both psycholinguistics and temperament to developmental stuttering in preschool children as well as considerations relative to bilingual populations, family structure, and various clinical settings will be discussed. Clinicians will learn what to include in an assessment and the empirical evidence explaining why each component is necessary to effectively diagnose stuttering in a preschooler.

Johnson, K. N., and Robinson, Jr., T. L. (March, 2008). Evidence-based assessment of stuttering in young preschool children: From the research lab to the clinic. Part II. Mini-seminar presented at the National Black Association of Speech Language and Hearing, Washington, DC.

This mini-seminar is Part II of a two-part seminar on the fundamental aspects necessary to conduct comprehensive evidence-based assessments of stuttering in the preschool population. Specifically, during Part II, clinicians will be presented with actual case studies as well as receive practical instruction on conducting disfluency counts and measuring speech rate from conversational samples. This seminar will give clinicians the opportunity to apply empirical evidence to actual case studies to determine whether or not a stuttering diagnosis is warranted.

Jones, R., **Conture, E.**, and Walden, T. (November, 2008). Emotional reactivity in childhood stuttering: Replication and extension. Poster presented at the Annual Conference of the American Speech Language and Hearing Association, Chicago.

The purpose of this study was to assess the relation between emotional reactivity and stuttering in preschool-age CWS (n = 12) and CWNS (n = 12). Methods included a micro-momentary behavioral analysis of emotional reactivity during narrative production. Results show how CWS and CWNS differ in terms of emotional reactivity, particularly relative to utterance initiation, and how these differences may contribute to childhood stuttering. Worked supported in part by NIH/NIDCD research grant 1 R01EC006477-01A2.

Jones, R., Fox, R. A., and Jacewicz, E. (November, 2007). Phonological processing and effects of concurrent cognitive load in stuttering. Poster presented at the annual ASHA convention, Boston, MA.

The purpose of this study was to compare the phonological processing abilities of adults who stutter (AWS) and those who do not stutter (AWNS) while performing a rhyme decision task under systematically varying degrees of cognitive load. Participants were nine AWS and nine AWNS who performed a battery of speech, language and hearing evaluations to determine eligibility for participation. To assess phonological processing, a timed rhyme decision task was used in which participants saw a word (the prime) followed by a second word (the target), and then had to indicate, via a key press, whether the two words rhymed. In order to increase cognitive load, the rhyme decision task was simultaneously paired with a short-term memory task in two-thirds of the trials, which consisted of a random sequence of upper-case letters (consonants only) that the subjects had to remember. The task was visually presented, and reaction times (RT) and judgment accuracy were measured. AWS had significantly longer RTs than AWNS across all rhyme conditions. Also, the accuracy of AWS decreased on the most difficult memory conditions. These results provide evidence that the phonological processing of AWS is more disrupted in comparison with AWNS as demands on the cognitive system increase. Research supported in part by NIH/NIDCD research grant 5R01DC000523-14.

Karrass, J., **Conture, E.**, Walden, T., and **Johnson, K.** (November, 2008). Is childhood stuttering related to emotional reactivity and emotion regulation? Poster presented at the Annual Conference of the American Speech Language and Hearing Association, Chicago.

The purpose of the present study was to assess relations among emotional reactivity, regulation and stuttering in preschool-age children. Participants were 44 preschol-age children, 22 CWS and 22 CWNS. Results indicated that female CWNS scored significantly higher on attention shifting and inhibitory control than CWS girls and all boys on attention shifting and inhibitory control. There was no significant differences in emotional reactivity. Findings suggest that differences in the ability to regulate attention and behavior may be part of chain of causal contributions to childhood stuttering. Research supported in part by NIH/NIDCD research grant 1R01DC0006477-01A2 and a Discovery grant from Vanderbilt University.

Karrass, J., Walden, T., **Conture, E.** and **Johnson, K.** (Submitted). Is childhood stuttering related to emotional reactivity and regulation?

The present study examined relations between preschool-aged children's emotional reactivity, emotion regulation and stuttering. Participants were 22 three-year-old children who stutter (CWS) and 22 three-year-old children who do not stutter (CWNS). Children's emotional reactivity and emotion regulation were assessed by a parent-report questionnaire. Findings indicated that child gender moderated the effects of talker group on emotion regulation. Specifically, whereas CWS boys did not differ from CWNS boys on Attention Shifting or Inhibitory Control, female CWNS scored significantly higher than CWS girls and all boys on Attention Shifting and Inhibitory Control. There were no statistically significant differences in emotional reactivity. Findings suggest that differences in the ability to regulate attention and behavior are associated with childhood stuttering. Research supported in part by NIH/NIDCD research grant 1R01DC0006477-01A2 and a Discovery grant from Vanderbilt University.

Leonard, L., **Camarata, S.**, Brown, B., and **Camarata, M.** (2008). The acquisition of tense and agreement in the speech of children with specific language impairment: Patterns of generalization through intervention. *Journal of Speech-Language-Hearing Research*, 51, 120-125.

Purpose: The goals of this investigation were to determine whether gains in the use of tense and agreement morphemes by children with specific language impairment (SLI) during a 96-session intervention period would still be evident 1 month following treatment and whether these treatment effects would be greater than those seen in children with SLI receiving otherwise similar treatment that did not emphasize tense and agreement morphemes.
Method: Thirty-three children with SLI (age 3;0 to 4;8 [years;months]) served as participants. The children participated in 1 of 3 treatment conditions. The conditions emphasized 3rd person singular –s, auxiliary is/are/was, or general language stimulation. The children's use of 3rd person singular –s, auxiliary is/are/was, and past tense –ed was assessed through probes administered throughout treatment and 1 month later.
Results: The children in the conditions that targeted 3rd person singular –s and auxiliary is/are/was showed significant gains on their respective target morphemes, and these gains were maintained 1 month later. These gains were significantly greater than the gains seen on the same morphemes by the children receiving general language stimulation. For most children, use of the target morphemes did not approach mastery levels by the end of the study.
Conclusion: Intervention that emphasizes morphemes that mark both tense and agreement can be relatively successful, with gains still apparent at least 1 month following intervention.

Ntourou, K., Buhr, A. P., and **Conture, E. G.** (2007, November) Childhood stuttering, MLU and function vs. content words: Preliminary findings. Poster presented at the annual ASHA convention, Boston, MA.

The purpose of this study was to examine stuttering on function and content words in relation to utterance length and complexity in preschool-age children who stutter (CWS). Results indicate that while function words are more likely to be stuttered than content words, utterance length relative to a child's MLU neither influences the distribution of function and content words across an utterance or nor whether a function versus word or a content word is stuttered. Findings were taken to suggest that the influence of MLU on stuttering is relatively independent of the influence of word class on stuttering. but that other "third-order" variable, for example, word position within the utterance, may better tie together these two seemingly independent influences on childhood stuttering. Research supported in part by NIH/NIDCD research grant 5R01DC000523-14.

Ntourou, K., and **Conture, E.** (November, 2008). Effects of concurrent cognitive processing on picture naming of preschoolers who stutter: Preliminary findings. Poster presented at the Annual Conference of the American Speech Language and Hearing Association, Chicago.

The purpose of this study was to assess the influence of changes in attention/monitoring on the speed and accuracy of preschool-age CWS and CWNS. In both focused (i.e., picture naming in presence of distractor pictures) and divided-attention (i.e, naming of picture while identifying another picture by button pushing) tasks, visual monitoring was the secondary task and picture naming the primary task. Results indicated that both talker groups were slower and less accurate in picture-naming during both divided- and focused-attention conditions relative to control. CWS did differ from CWNS in the relationship between accuracy and speed of picture-naming during attentionally-demanding tasks. Research supported in part by NIH/NIDCD research grant 1R01DC0006477-01A2.

Ntourou, K., Conture, E. G., and Walden, T. (Submitted). Effects of concurrent cognitive processing on picture naming of young children who stutter.

The purpose of this study was to assess the influence of changes in attention/monitoring on the speech reaction time (SRT) and accuracy of children who do (CWS) and do not stutter (CWNS) during a picture-naming task. In both focused (i.e., naming of pictures in presence of distractor pictures) as well as divided-attention (i.e., naming of picture while detecting the presence of another picture) tasks, a visual monitoring task was used as the secondary task, while the primary task involved picture naming. Dependent variables were the accuracy and latency (SRT) of picture naming. Results indicated that both CWS and CWNS demonstrated significantly slower SRT during the most attentionally demanding condition, the divided-attention condition; and significantly faster SRT during the control condition. However, contrary to predictions, CWS did not exhibit greater decrements in SRT when compared to their normally fluent peers. Additionally, there was no significant difference in error rate between CWS and CWNS in any of the three conditions. Finally, during the divided-attention condition, for CWNS but not CWS, there was a significant positive correlation between speed and accuracy, indicating that as SRT increased (slower naming) so did errors. Findings were taken to suggest that although preschool-age CWNS and CWS did not differ in their ability to allocate and regulate attentional resources, they did differ in their speed/accuracy relationships during attentionally-demanding tasks. Research supported in part by NIH/NIDCD research grant 1R01DC0006477-01A2.

Pawlowska, M., Leonard, L.B., **Camarata, S.M.**, Brown, B., **Camarata, M.N.** (2008). Factors accounting for the ability of children with SLI to learn agreement morphemes in intervention. *Journal of Child Language*, 35, 25-53.

The aim of this study was to uncover factors accounting for the ability of children with specific language impairment (SLI) to learn agreement morphemes in intervention. Twenty-five children with SLI who participated in a six-month intervention program focused on teaching third person singular -s or auxiliary is/are/was showed a wide range of use of the target morpheme after intervention. Regression analyses showed that age and two factors expected to be related to agreement--the use of noun plural -s and subject/verb constructions prior to intervention--significantly predicted progress in the acquisition of agreement morphemes. In contrast, the pretreatment use of morphemes hypothesized to be unrelated to agreement was not a significant predictor of progress. The results indicate that the ability of children with SLI to learn agreement morphemes relies on their prior ability to use noun plural and subject/verb constructions. See Table 1.

Table 1. A summary of the use of the target agreement morphemes and the predictor measures at Time 1 (T1)

Measure	Mean	Standard Deviation	Range
T1 agreement morpheme	2.7	5.2	0–18
T1 noun plural	49.7	36.2	0–100
T1 subject/verb	46.3	22.6	14.3–85.2
T1 MLU	2.3	0.8	1.4–4.8
T1 age	3;5	0.5	3;0–4 ; 4

Richels, C., **Buhr, T.**, **Ntourou, K.,** and **Conture, E.** (Submitted). Does utterance position mediate the relation of word class and utterance complexity relative to the loci of stuttering in childhood?

The purpose of the present investigation was to examine the influence of utterance complexity and sentence position on the tendency to stutter on function words in young children who stutter (CWS). In two separate studies (Studies 1 and 2), each using two different groups of 30 preschool boys who stutter between the age of 3;0 and 5;11, measures of stuttering, word class, utterance complexity, and utterance position were obtained from transcriptions of conversational speech. Results of Study 1 indicated that children tended to stutter on function words, but that this tendency was not greater for complex than it was simple utterances. Results of Study 2, using sentence position and an relative measure of utterance complexity, indicated that children exhibited a tendency to stutter on function words mainly at the utterance-initial position, a tendency that increased with increases in utterance complexity. Findings were taken to suggest that word class, utterance complexity and utterance position interact to influence the loci of stuttering in preschool children who stutter. Specifically, for these preschool-age CWS, increases in utterance complexity appear to contribute to increases in stuttering on utterance-initial words, with the tendency of function words to occur on utterance-initial words significantly contributing to the frequency with which preschool children to stutter on function words. Research supported in part by NIH/NIDCD research grant 5R01DC000523-14 and NIH training grant T32HD07226.

Schneider, S.L., **Haack, L.**, Owens, J.**, Herrington, D.**, and **Zelek, A.** (In press). An interdisciplinary treatment approach for soldiers with TBI/PTSD: Issues and outcomes. *Perspectives on neurophysiology and neurogenic speech and language disorders*. Also an invited presentation at the American Speech and Hearing Association Meeting, Chicago, November, 2008.

While the co-morbidity of symptoms associated with traumatic brain injury (TBI) and post-traumatic stress disorder (PTSD) in the injured military population is being discussed and researched, those of us in the rehabilitation fields need to be ready to serve this complex population. Designated as the "signature injury of this war" we are challenged to provide the best services with limited research and evidence based practices to guide us. We will present an interdisciplinary treatment approach based on our experience as a Center that has provided services for individuals with TBI for over 20 years and discuss how this population is similar and different. We will share with you what we have learned (outcome measures) and are continually learning. Our goals will be to present strategies to help guide the treatment for soldiers with TBI/PTSD, and to assist in knowing when to treat, what to treat and how to address the TBI and PTSD components.

Schwenk, K., **Conture, E.**, and Walden, T. (2007). Reaction to background stimulation of preschool children who do and do not stutter. Journal of Communication Disorders, 40 (2), 129-141.

This study investigated the maintenance of attention and adaptation to background stimuli of preschool children who do (CWS) and do not stutter (CWNS). Participants were 13 monolingual, Standard American English speaking, 3–5-year-old CWS and 14 CWNS. Results indicated that CWS were significantly more apt than CWNS to attend to or look at changes in background stimuli, although there were no significant differences between groups in duration and latency of these looks. Findings suggest that preschool CWS are more reactive to, distracted by, and slower to adapt and habituate to environmental stimuli than their CWNS counterparts. Research supported in part by NIH/NIDCD research grant 1R01DC0006477-01A2.

Wertz, R.T., **de Riesthal, M.,** Irwin, W.H., and Ross, K.B. (In press). Department of Veterans Affairs contributions to treatment outcomes research in aphasia. *Aphasiology*

This article provides a historical perspective of the contributions of the Department of Veterans Affairs to treatment outcomes research in aphasia. Military hospitals and VA Medical Centers were the leaders in early research on aphasia treatment and continue to provide innovation in treatment outcomes research.

D. Speech and Language Science — Basic

Abel, A.D., and **Schuele, C.M.** (June, 2007). An examination of the influence of three cognitive-linguistic variables on children's incidental word learning. Poster presented to the Annual Symposium on Research in Child Language Disorders, Madison, Wisconsin.

Purpose: This study examined the influence of prior vocabulary knowledge, phonological memory, and phonological awareness on word learning. Two research questions were addressed: (a) Are prior vocabulary knowledge, phonological memory, and/or phonological awareness associated with word learning? And (b) Does vocabulary knowledge, phonological memory, or phonological awareness predict word learning ability?
Method: Participants (M age = 5;0, n = 35) were administered measures of vocabulary knowledge, phonological memory and phonological awareness. A story was written that introduced the children to 19 unfamiliar words. The story was read twice and children were tested on their receptive knowledge of the unfamiliar words prior to the first story reading and after the second story reading. Acquisition of words across the two story readings was analyzed using a correlation analysis and a series of fixed-order multiple-regression analyses to examine the contribution of the three variables to word learning.
Results: Phonological awareness and prior vocabulary knowledge were found to be significantly correlated with the outcome variable. In a multiple regression analysis, phonological awareness when entered after pre-test predicted a significant amount of variance in the outcome variable but not when entered after pre-test and prior vocabulary knowledge.
Conclusions: The results support the view that phonological awareness and prior vocabulary knowledge are associated with incidental word learning. Within the study design, it was not possible to clearly differentiate the influence of these two variables. This research project was supported by a Students Preparing for Research and Academic Careers (SPARC) Award from the American Speech-Language-Hearing Association, to the first author.

Alaskary, H.A., and **Ohde, R.N.** (In preparation). Developmental effects of age and gender on normalization.

Perceptual normalization is a listener's ability to reduce the amount of information, noise, and variability that is inherent of the spectra that distinguishes the phonetic segments produced by men, women, and children [Klatt, *J. Phonetics. 7,* 279-312 (1979); Ryalls and Pisoni, *Dev. Psych. 33,* 441-452 (1997)]. The current investigation was designed to investigate the effects of *speaker* age and gender on the perceptual normalization abilities (in terms of identification accuracy) of children and adults. Two children (4 years of age), two adult females, and two adult males will serve as the speakers for the recording of the stimulus material. A total of 30 subjects will serve as listeners in the perceptual experiments. Listeners will be divided into three groups. Ten young children (ages 4:0 to 4:6), ten older children (ages 9:0-9:6), and ten adults. Word lists from the *Word Intelligibility by Picture Identification (WIPI)* test will serve as the stimuli for the experiment. Each subject will participate in two main types of speaker conditions. The single speaker conditions include: 1) Child Only, 2) Adult Female Only, and 3) Adult Male Only. The mixed speaker conditions include: 1). Child speakers, 2) Adult Female Speakers, 3) Adult Male Speakers, 4) Adult Male and Child speakers 5) Adult Female and Child Speakers, 6) Adult Male and Female speakers, and 7) Adult Male, Female, and Child speakers. Percent correct word identification will be calculated for each test condition. Predicted results are that children will perform with less accuracy than adults; however, their scores should show an increase in performance in the following multiple speaker conditions: female speakers, child speakers; female and child speakers.

Barako Arndt, K., and **Schuele, C.M.** (November, 2008). Complex syntax production in children with SLI—longitudinal data. Technical session presented to the Annual American Speech and Hearing Association Conference, Chicago, Illinois.

Research to-date suggests that children with SLI develop complex syntax (CS) later and with more difficulty than typically developing peers. Longitudinal data on the development of CS in children with SLI is necessary to further understand SLI and to develop clinical intervention with this population. In the present study, longitudinal spontaneous language samples were analyzed for inclusion of thirteen CS types, density of CS, and inclusion of obligatory markers. Data was analyzed for patterns of use and error. Findings suggest that children with SLI demonstrate highly variable growth in CS production and have difficulty with inclusion of obligatory markers. Funding: NIH/NIDCD RO3 DC 007329 (PI: Schuele); American Speech-Language-Hearing Foundation (Schuele); Schubert Child Development Center at Case Western Reserve University (Schuele).

Barako Arndt, K., and **Schuele, C. M.** (Under review). Production of infinitival complements by children with specific language impairment.

Purpose: The purpose of this study was to describe the production of infinitival complements, an early developing complex syntax form, by children with specific language impairment (SLI) as compared to a group of typical language learners (TL) matched for mean length of utterance (MLU).
Method: Spontaneous language samples were analyzed for infinitival complements (catenatives and true infinitives) in a replication and extension of Eisenberg (2003). Participants included children with SLI (n = 19; 5;2 to 7;10) and children with TL (n = 19; TL; 3;0 to 5;9).
Results: There was no group difference in the number of infinitival complements. However, the SLI group produced more true infinitives than the TL group. The TL group produced more two-noun infinitives than the SLI group. There was no group difference on the number of different complement taking verbs. The SLI group was less accurate than the TL group on inclusion of obligatory infinitival to, with 80.21% accuracy (SD = 29.42) and 99.81% accuracy (SD = 0.85), respectively.
Conclusions: The children with SLI did not have problems with the clausal structure of infinitives. However, they had difficulty with the specific grammatical requirements of infinitival clauses, omitting to more than often than MLU-matched children.

German, S.R., and **Ohde, R.N.** (Submitted). Vowel perception from static and dynamic cues in young children and adults.

The purpose of this study was to determine whether children give more perceptual weight than do adults to dynamic spectral cues versus static cues, when identifying vowel sounds. Three experimental stimulus sets were presented, each with 30 ms stimuli. The first consisted of unchanging formant onset frequencies ranging in value from frequencies for [i] to those for [ɑ], corresponding to a bilabial stop consonant. The second two consisted of either an [i] or [ɑ] onset frequency with a 25 ms portion of a formant transition whose trajectory was toward one of a series of target frequencies ranging from those for [i] to those for [ɑ]. Ten children between the ages of 3;8 and 4;1 and a control group of 10 adults identified each stimulus as [bi] or [bɑ]. The results showed developmental effects: the children relied more heavily than the adults did on the static formant onset frequency cue to identify the vowels, while the adults appeared to give more equal weight to both static and dynamic cues than the children did. For example, Figure D-1 illustrates that children hear fewer of the F2 [ɑ] onset stimuli as [i] compared to

adults. Thus, they appear to attend more to the [ɑ] onset than do the adults. These findings contradict the Developmental Perceptual Weighting Shift theory and are discussed in relation to this theory and other current research on the development of vowel perception.

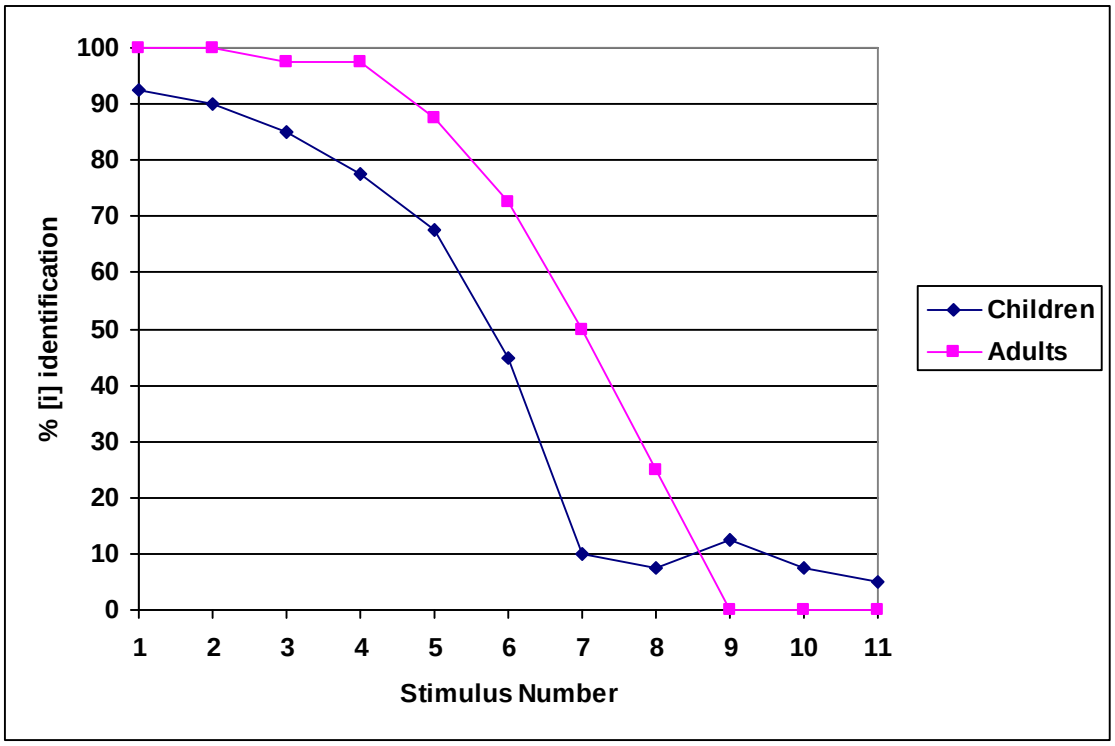

Figure D-1. Mean percent [i] responses of children and adults for the F2 [ɑ]-onset condition. German & Ohde

Gibson, T., and **Ohde, R.N.** (In preparation). Acoustic correlates of infants' concurrent babble and words: F2 Frequency and F2 Variability.

Purpose: This study examined potential speech production differences between babble and words across place of articulation for voiced stop consonants [b], [d], and [g], using spectral measurements of the second formant (F2) for early CV productions.
Method: A total of 1182 stop CV productions were collected from ten children, ages 17-22 months, who were producing concurrent babble and words. Spectral measurements of F2 yielded F2 onset (first glottal pulse) and F2 vowel (vowel target steady-state) frequencies for 500 babble and 682 word productions. F2 onset represents the anterior-posterior movement of the tongue for stop place of articulation. F2 vowel represents the front-back movement of the tongue for vowels. Mean F2 onset and F2 vowel frequencies and their mean standard deviations (SD), SD onset and SD vowel, respectively, were statistically analyzed for babble and words across place of articulation.
Results: As shown in Table D-1, second formant measurements (F2 onset and F2 vowel) showed no speech motor differences for babble versus words. In addition, no differences were revealed in variability (SD) of speech motor movements for babble versus words. However speech production differences were noted across place of articulation. Variability parameters, SD onset and SD vowel, were significant for place of articulation. SD onset, which is indicative of the variability of tongue movement, revealed that

stability of motor movement for [b], [d], and [g] was statistically different across all stop consonant comparisons. SD vowel was significantly different for alveolars when compared to bilabials and velars indicating less diverse vowel productions for alveolars. F2 onset, which provides information about anterior and posterior tongue movement, showed that [b], whose production is not constrained by tongue movement, was significantly different from [d] and [g], whose productions are shaped by constraints of opposite tongue movements. Alveolar and velar F2 onsets were marginally significant in differentiating the anterior tongue movement of [d] from the posterior tongue movement of [g]. F2 vowel revealed no statistical significance across place of articulation.

Conclusions: The results of this study support the continuity theory, which suggests that the articulatory gestures implemented in babble continue into word productions. In regard to place of articulation of stops, the toddlers differentiated motor control for consonantal occlusion of bilabials versus alveolars and velars. However, children varied in their ability to differentiate motor control for consonantal occlusions of alveolars versus velars. The importance of differences in speech motor variability was clearly observed for SD onset which showed that variability provides information about children's early speech motor movements for distinctive consonant place of articulation. [Work supported by NIH grant DC4034.]

Table D-1. Means (Hz) and standard deviations (Hz) for F2 Onset, SD Onset, F2 Vowel, SD Vowel, for babble (B) and words (W) across place of articulation. Gibson & Ohde.

		F2 Onset		SD* Onset		F2 Vowel		SD* Vowel	
Stop		B	W	B	W	B	W	B	W
[b]	Mean	1902	1850	403	477	2241	2320	527	673
	SD*	164	132	150	171	312	172	281	201
[d]	Mean	2762	2713	304	330	2563	2425	482	478
	SD	250	264	121	81	266	350	243	159
[g]	Mean	2496	2410	722	626	2424	2371	694	609
	SD	484	547	214	266	388	494	206	279

*SD = Standard Deviation

Gibson, T., and **Ohde, R.N.** (2007). F2 locus equations: Phonetic descriptors of coarticulation in 17-21 month old children. *Journal of Speech, Language, and Hearing Research* 50, 97-108.

The general purpose of this research was to describe coarticulation across voiced stop consonant place of articulation in ten children less than two years of age. A total of 1182 voiced stop CV productions was analyzed using the locus equation metric, which yielded three regression lines that described the relationship of F2 onset and F2 vowel for /bV/, /dV/, and /gV/ productions. The results revealed significant differential effects for slope and y-intercept as a function of stop consonant place of articulation. As illustrated in Figure D-2, the ordering of the mean slope values for stop consonant place

of articulation was /g/ >/b/ and /d/ indicating that /g/ was produced with significantly greater coarticulation than /b/ or /d/. However, the unique vowel allophonic pattern of [g] coarticulation reported in the literature for English-speaking adults was generally not learned by these young children. Group and individual coarticulation trends are described in relationship to developmental theories of sound acquisition. Results suggest that early coarticulation patterns are phoneme specific. [Work supported by NIH grant DC4034.]

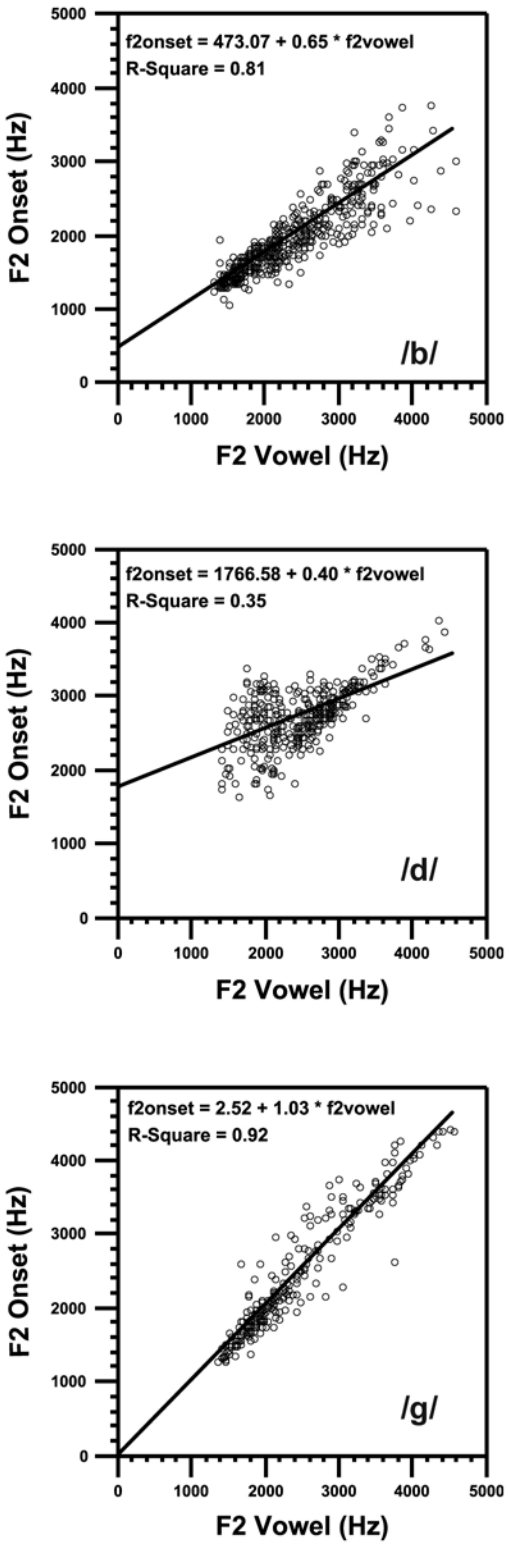

Figure D-2. Group mean locus equations of /b/, /d/, and /g/ for ten children. Gibson & Ohde (2007).

Guillot, K.M., and **Ohde, R.N.** (In preparation). Development of speech perception of nasal consonants [m n] in children who use cochlear implants and in children with normal hearing.

The purpose of this study is to examine the development of speech perception in young children who use cochlear implants and in children who have normal hearing as a function of systematic variation in place of articulation of nasal consonants. The performance of the children who use cochlear implants will be compared to that of chronologically age-matched and hearing age-matched children with normal hearing, which will provide information regarding the development of speech perception in children who use cochlear implants as it relates to children with normal hearing. The participants will be presented with stimuli that were developed and used in a previous study conducted by Ohde et al. (2006). The speech stimuli will consist of nasal consonant + vowel syllables comprised of [m n] and [i æ u ɑ]. Four stimulus segments were generated using a waveform-editing program into the following four segment types, as seen in Figure D-3. The nasal feature was selected because it provides important static (nasal murmur) and dynamic cues (formant transitions) for perception of place of articulation. These cues also provide an important opportunity to assess developmental models of speech perception such as the sensory and acoustic discontinuity hypotheses. We predict that the children who use cochlear implants will utilize different acoustic cues than children with normal hearing in identifying nasal phonemes. In addition, it is predicted that the children who use cochlear implants in the study will rely more on the dynamic cues (formant transitions) for identifying the place of articulation rather than static cues (consonant noise). Finally, it is expected that children in particular will benefit from a combination of murmur plus vowel cues indicating the importance of spectral discontinuities in perceptual development.

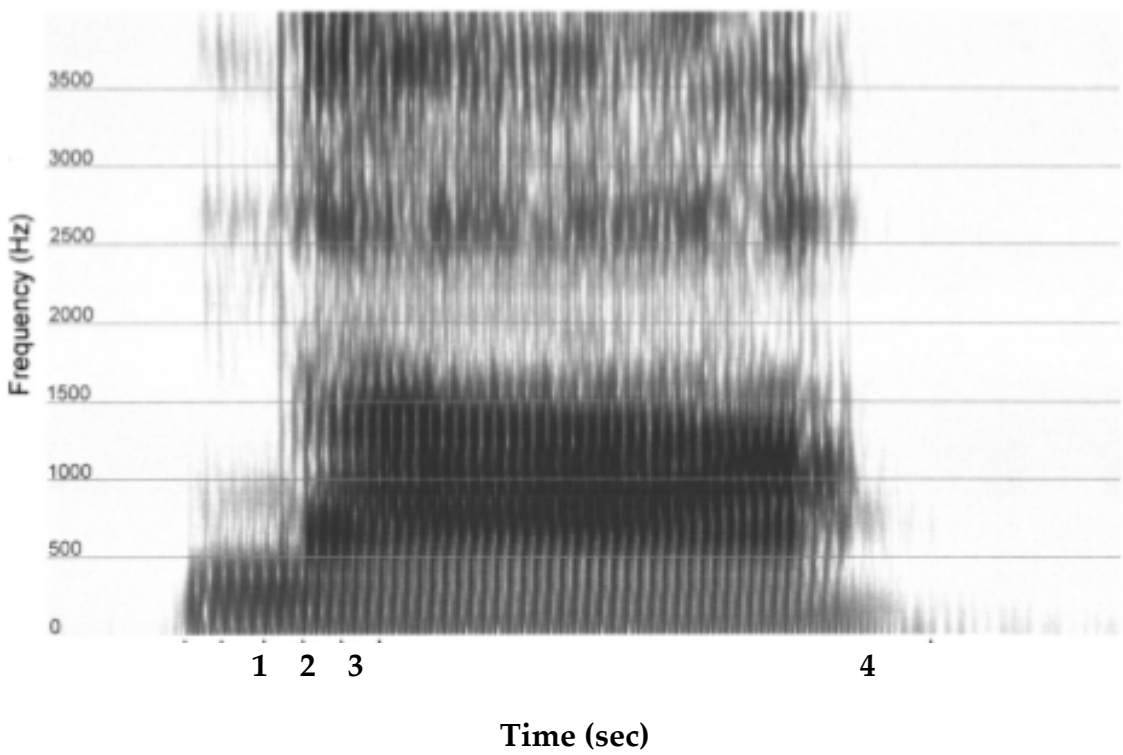

Figure D-3. (1) 50-ms murmur (50M) – the last 50 ms of the murmur; (1 to 3) 25-ms murmur + 25-ms transition (MT) – the last 25 ms of the murmur and the first 25 ms of the immediately following vowel; (2) 50-ms transition (50T) – the first 50 ms of the vowel; and

(1 to 4) full syllable (FS) – the complete syllable including the full murmur and the full transition. Guillot & Ohde.

Guillot, K.M., Schuele, C.M., and **Tharpe, A.M.** (November 2007). Morphological markers in young children who use cochlear implants. Poster Presentation at the American Speech and Hearing Association Convention, Boston, MA.

The purpose of this study was to evaluate the comprehension and production of morphological markers in younger children who use cochlear implants (CI). The participants were administered comprehension and production probes that assessed their morphological marking abilities. Comparisons were made between the performance of the younger and older children on the probes. It was predicted that the CI group would perform worse on the comprehension and production probes when compared to the older CI group. Additionally, the younger CI group would demonstrate a larger gap between performance on the comprehension and production probes with comprehension being superior. The results of the study were that the CI group performed more poorly than the CA group on measures of both comprehension and production of morphological markers. The CI group also performed more poorly than the HA group on measures of production of morphological markers. See Figure D-4**.** However, the CI group performed similarly to the HA group on measures of comprehension of morphological markers. The CI group demonstrated a gap between their performance on the comprehension and production tasks, where comprehension was superior to production.

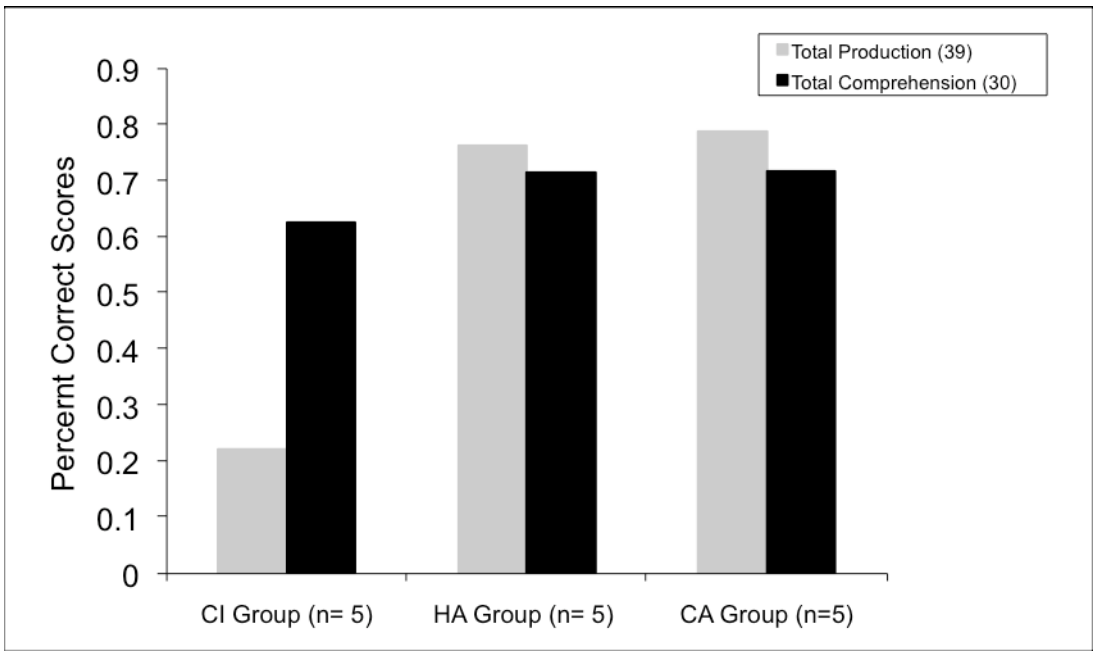

Figure D-4: Comparsion of comprehension and prodcution of morphological markers of the cochlear implant (CI) group, hearing-age matched (HA) group, and chronological-age matched (CA) group. Guillot *et al.*, 2007.

Guillot, K.M., Schuele, C.M., and **Tharpe, A.M.** (June 2008). Finite and Nonfinite Morphological Marking in Children who use Cochlear Implants. Poster Presentation at the Symposium of Research of Child Language Disorders, Madison, WI.

The purpose of this study was to evaluate the production of finite (i.e., third person singular and regular past tense) and nonfinite (i.e., plural and possessive) morphological markers in younger children who use cochlear implants (CI) when compared to children with normal hearing. The participants included three groups of children with five children in each group (i.e., cochlear implant (CI), chronological age-matched (CA), and hearing age-matched (HM). They were administered four different production tasks that included the Test of Early Grammatical Impairment Third Person Singular Probe and an adapted Past Tense probe, Oetting and Rice (1993) adapted plural probe and an experimental possessive probe. The CI group performed significantly worse than the CA and HM groups on both finite and nonfinite morphological markers. See Figure D-5**.** Children who use cochlear implants need direct and explicit training of morphological markers so that their production of these markers can resemble that of children with normal hearing.

The children in the CI group were less accurate than the children in the CM and HM group on the production of both finite and nonfinite morphological markers. Differences in production of morphological markers were expected between the CI and CM children. However, a difference in production between the CI and HM children was not expected. The children within the CI group and CM group were equally accurate on finite and nonfinite morphological markers, whereas the HM children were more accurate on nonfinite markers than finite markers. Based on the age of the CM group, we expected equivalent performance. Likewise, the performance pattern of the HM group was expected; differences in accuracy between finite and nonfinite markers has been reported for this age group (e.g., Rice & Oetting, 1993). Based on hearing age, we expected the CI group to perform similarly to the HM group, such that they would have been more accurate on nonfinite markers than finite markers. However, the results were not consistent with our expectation.

The lack of difference in accuracy between finite and nonfinite may be a function of the point of development captured. Three of the CI children were at very low levels of accuracy, questioning whether they had moved beyond emergence. To assess whether CI children evidence a difference in nonfinite marking and finite marking across development, it is necessary to examine older children as well as track children longitudinally to document the path of morphological development in children who use cochlear implants.

The acquisition of finite and nonfinite morphological marking is challenging for children who use cochlear implants. The difficulty that these children experience in the production of morphological markers may be reflective of a broader language problem. The current study did not evaluate the broader language abilities of these children. However, there is information regarding the vocabulary (PPVT-III) abilities of these children. With this limited information, we see that the mean vocabulary score for CI group was 1.5 standard deviations below the normative mean. In contrast, the mean finite and nonfinite percent correct of the CI group was more than three standard deviations below that of the CM children.

Three possible explanations for the limited performance of the CI group can guide further investigation. First, despite the technological advances of cochlear implants, the auditory signal is not comparable to the signal in a normal hearing mechanism. In addition, even when children receive a cochlear implant at the earliest age of 12 months, there has been a substantial period of prenatal and postnatal auditory deprivation. The cochlear implant may provide a sufficient signal to develop some aspects of spoken language (e.g., vocabulary). However, the perceived signal may not be adequate for the development of aspects of language that rely on perception of auditory cues of low salience (e.g., morphological marking). Second, limited verb vocabulary could be linked to the production of finite morphological markers such that children with larger verb vocabularies are more accurate at marking finiteness (Leonard, Miller & Greber, 1999). The children in the CI group had overall lower vocabulary scores than the children in the CM group, which could also mean that they have less verbs in their lexicons. Third, it is possible that for at least some children with hearing loss the course of language acquisition has some similarity to the course of development for children with specific language impairment. It is not clear why some children with hearing loss appear much more able to compensate for auditory deprivation and degradation than other. To explore the issues of delay versus deviance, if children who use cochlear implants have a language delay or deficit, ideally a longitudinal study would

need to be conducted so that individual pattern of development could be documented in detail to explore group trends and individual difference.

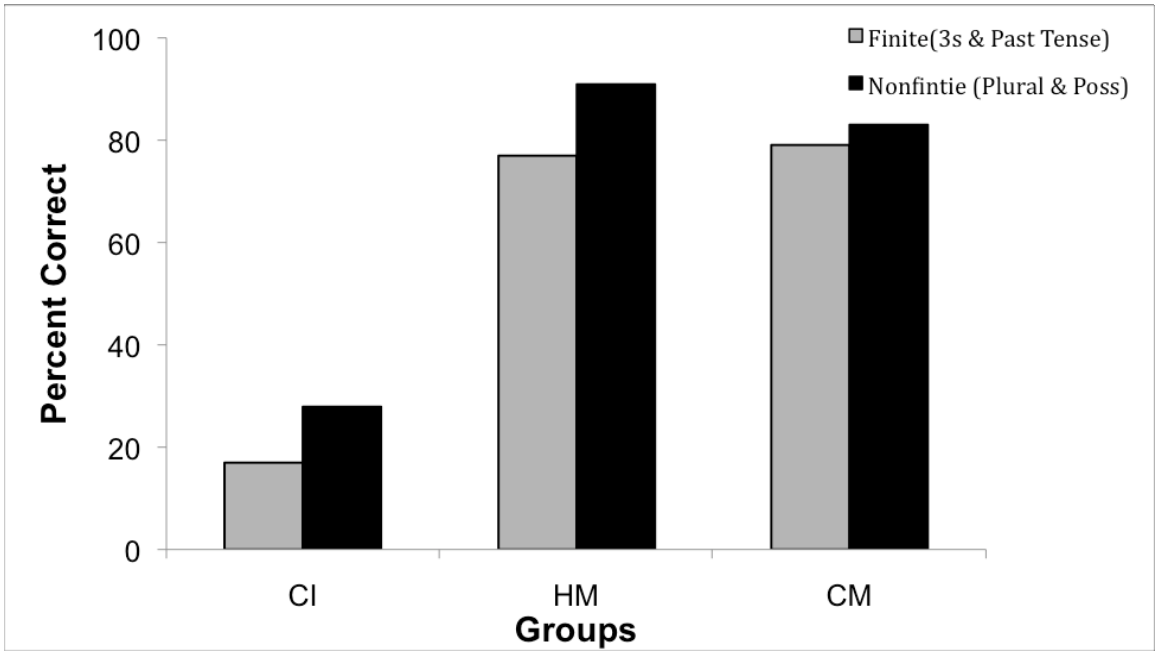

Figure D-5: Comparison of finite and nonfinite morphological marking by the cochlear implant (CI) group, the hearing-age matched (HM) group, and the chronoloigcally-age matched (CM) group. Guillot *et al.*, 2008.

Kendrick, K., and **Schuele, C.M.** (November, 2008). Is complex syntax really later language development? Poster session presented to the Annual American Speech and Hearing Association Conference, Chicago, Illinois.

Although often characterized as “later language development”, complex syntax (CS) emerges between two and three years of age. By four, children produce a variety of CS types, yet this early development of CS is minimally described in language acquisition textbooks. Thus, SLPs may have a limited understanding of CS development. This language development case study of a typically developing boy highlights the initial acquisition of CS. Analysis of monthly language samples and parent diaries illustrates that initial CS proficiency was contemporaneous with the achievement of other early grammatical milestones (e.g., grammatical morphemes, subject-auxiliary inversion). Practice implications are discussed. . Funding: NIH/NIDCD RO3 DC 007329 (PI: Schuele)

Lee, M., **Schuele, C. M.**, **Barako Arndt, K.**, **Lineback, A.**, Rosenthal, J., **Spencer, E.**, and Foran, C. (November, 2008). SES influences on preschoolers' performance on the Preschool Language Scale and the Peabody Picture Vocabulary Test. Poster session presented at the Annual Convention of the American Speech-Language-Hearing Association, Chicago, IL.

Norm-referenced instruments are widely used in evaluating the language skills of preschool children to make diagnostic decisions. In studies of low income preschoolers from Nashville, TN, Qi, Kaiser and colleagues reported that the mean performance of low income children was significantly below the normative mean of 100 on the PPVT and PLS, yet the groups' performance approximated a normal distribution. In this study, we compare their findings to the performance of a group of middle income children (n = 100) from Nashville, TN. The middle income children performed significantly above the normative mean. Implications for practice are considered. . Funding: NIH/NIDCD RO3 DC 007329 (PI: Schuele)

Oakey, M.A., and **Ohde, R.N.** (2007). The development of relative amplitude changes across acoustic discontinuities in nasal + vowel syllables. *J. Acoust. Soc. Am*. 121, 3188 (A). Portions of this paper were also presented at the convention of the American Speech-Language-Hearing Association in Boston, Massachusetts, November (2007).

In adult productions of nasal + vowel syllables, relative amplitude changes occur in various frequency regions across acoustic discontinuities and provide important cues as to the place of articulation of nasal consonants. The purpose of this study was to investigate the development of relative amplitude changes in children as potential acoustic correlates to place of articulation. Four age groups of 8 participants each (3, 5, 7, adults) served as speakers. Participants produced five productions each of CV syllables comprised of [m] and [n] in the context of four vowels (/*a* æ i u/). As shown in Figure D-6**.**, these syllables were segmented into approximately 25 ms segments of the murmur and 25 ms segments of the vowel bordering the period of discontinuity. The relative amplitude changes in low and high frequency ranges from the murmur to the vowel were determined using summed amplitude information from fast Fourier transform (FFT) analyses. Main effects showed significance for both the factors of nasal place of articulation and vowel. The magnitude and predictability of the /m/ vs. /n/ acoustic differences were such that they support the salience of acoustic discontinuities in the perception of place of articulation. As illustrated in Figure D-7, adult /nV/ productions were significantly different from child productions, but /mV/ productions were not. This result suggests that children are developmentally different from adults in the production of the alveolar nasal at least until the age of 7. [Work supported by NIH (DC00464 and DC00523-08) and an ASHA SPARC Award.]

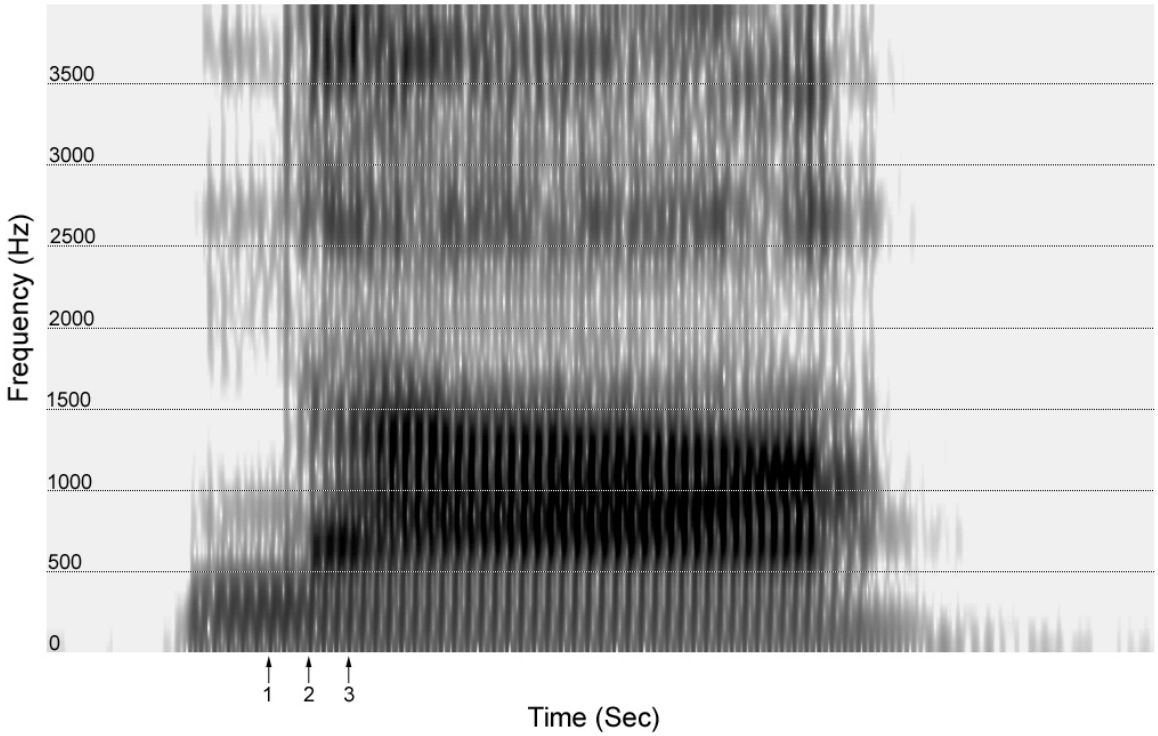

Figure D-6. A spectrographic illustration of an adult male's production of [n*a*]. The segmentation marks (SMs) represent the following two stimulus conditions: 25-ms murmur (25M – SMs 1 to 2) and 25-ms transition (25T – SMs 2 to 3). Oakey & Ohde (2007).

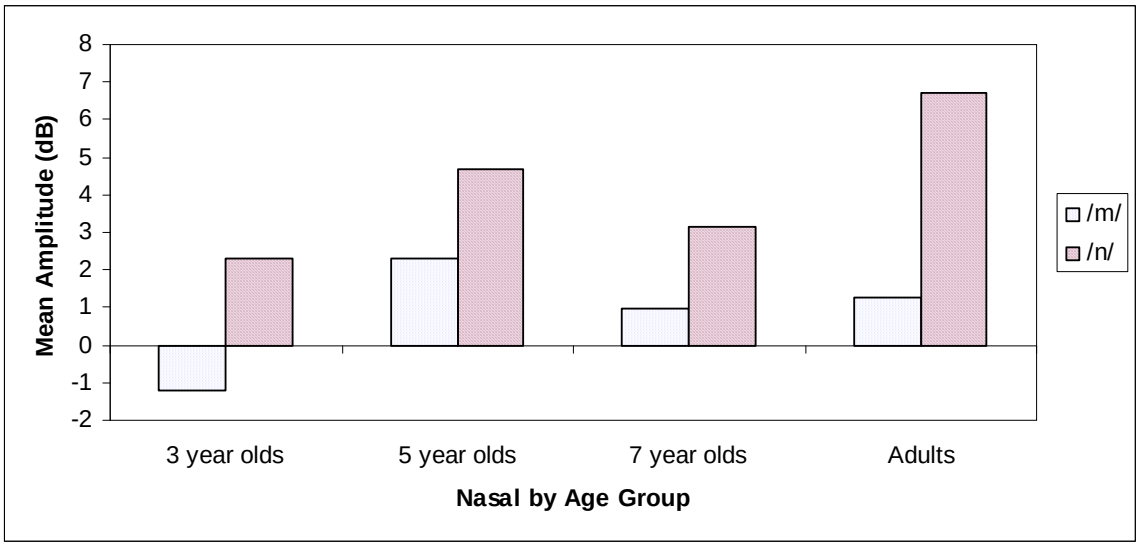

Figure D-7. Mean relative amplitude (in dB) of place of articulation of nasals across age group. Oakey & Ohde (2007).

Ohde, R.N. (In preparation). Children's perception of static noise and static formant cues to stop-consonant place of articulation.

Children's processing strategies appear to favor dynamic cues such as formant transitions as compared to static cues such as F2 onsets and noise bursts. The purpose of this research was to examine children's perception of place of articulation based only on static cues. Ten children at each of five age levels (3, 4, 5, 6, and 7) and a control group of 10 adults identified synthesized stop consonants [d g] in two vowel contexts [i *a*]. The synthesis parameters included variations in F2 onsets and stop-consonant noise bursts. The F2 onsets were either "appropriate" or "neutral" for place of articulation. The noise bursts were short (10 ms), long (25 ms), or not present (0 ms). Preliminary data show that the F2 onset is not as salient in children's perception as in adults' perception. In addition, children more often than adults categorized neutral F2 onset stimuli as ambiguous indicating stronger category formation in the latter than former groups. The role of noise bursts was more salient in adult perception than child perception. However, as Figure D-8 illustrates, when static formant onsets were neutralized in the [*a*] context, all subject groups including 3-year-olds appropriately used burst cues in the perception of [g]. The findings will provide information on the role of "static" cues, on the perceptual integration of "static" noise and formant cues, and on the influence of sound category formation in perceptual development. [Work supported by NIH grant DC00464 and a Vanderbilt University Research Council Grant.]

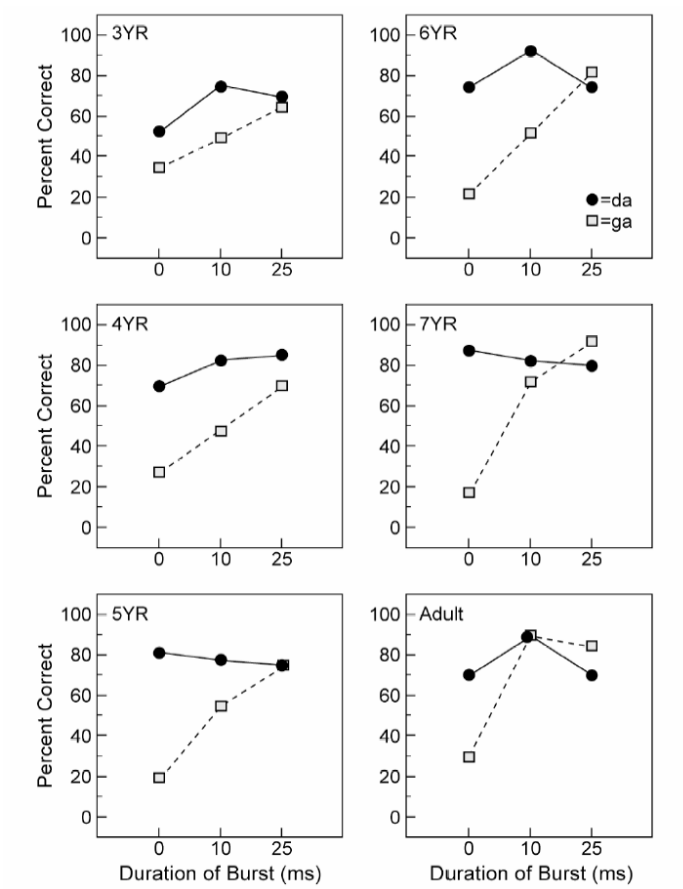

Figure D-8. Correct percent [d] and [g] responses as a function of burst duration and listener age group. Ohde.

Ohde, R.N., and **Camarata, S.M.** (In preparation). Cue weighting of static and dynamic vowel properties by adults and children with normal language and specific language impairment.

The purpose of this study was to determine whether children with and without language impairment give more perceptual weight than do adults to dynamic spectral cues versus static cues, when identifying vowel sounds. Three experimental stimulus sets were presented, each with 30 ms stimuli. The first consisted of unchanging formant onset frequencies ranging in value from frequencies for [i] to those for [ɑ], corresponding to a bilabial stop consonant. The second two consisted of either an [i] or [ɑ] onset frequency with a 25 ms portion of a formant transition whose trajectory was toward one of a series of target frequencies ranging from those for [i] to those for [ɑ]. Ten typically developing children between the ages of 3;8 and 4;1, nine children with specific language impairment (SLI) between the ages of 5;1 and 6;11, and a control group of 10 adults identified each stimulus as [bi] or [bɑ]. The results illustrated in Figures D-9 and D-10 showed developmental effects in that the typically developing children relied more heavily than the adults did on the static formant onset frequency cue to identify the vowels. The SLI children followed one of two perceptual profile patterns: 1) nonrandom perception of [ɑ] onset stimuli, but random perception of [i] onset stimuli; and 2) nonrandom perception of both [i] onset and [ɑ] onset stimuli, but phonetic boundaries different from typically developing children and adults. The results were discussed in regard to the Developmental Perceptual Weighting Shift theory, and perceptual profile differences in SLI children.

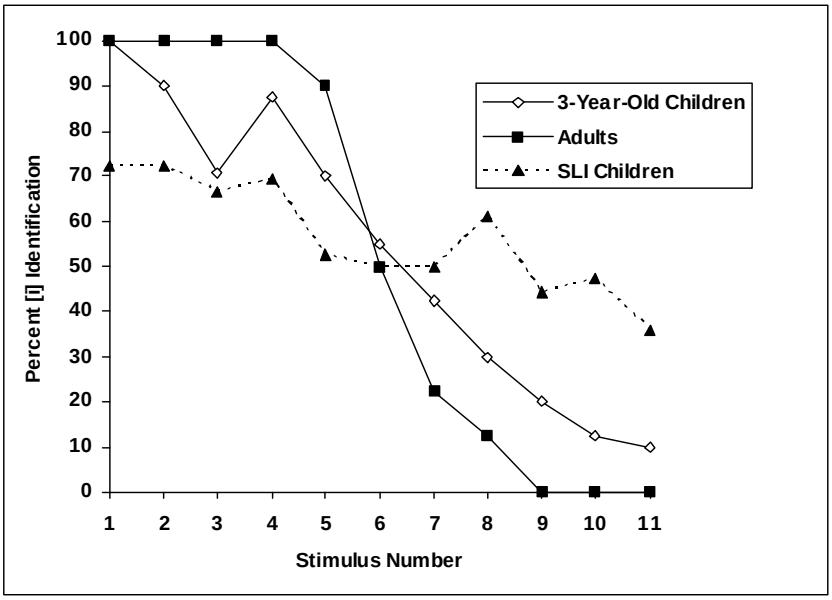

Figure D-9. Mean percent [i] identification for the F2 [i]-onset condition. Ohde & Camarata.

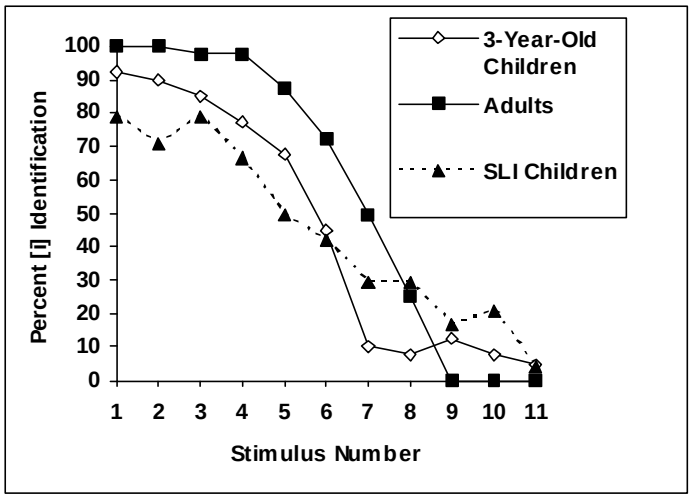

Figure D-10. Mean percent [i] identification for the F2 [ɑ]-onset condition. Ohde & Camarata.

Ohde, R. N., and Gibson, T. (In preparation). Longitudinal analysis of stop consonant-vowel productions of preterm and full term infants: A locus equation approach.

Researchers investigating prelinguistic speech have suggested that qualitative differences in consonant-vowel (CV) productions may be predictive of later speech production skills [Stoel-Gammon, *First Language* 9, 207-224 (1989)]. Qualitative differences in CV productions have been indicated in the babbling of preterm infants when compared to full term infants [Oller et al., *Journal of Child Language* 21, 33-58, (1994)]. The purpose of the current study was to investigate longitudinally the developmental trends in babbling for preterm and full term infants using locus equations to quantify the acoustic parameters. Locus equations use the F2 transition to obtain regression lines that represent relational invariant acoustic patterns for phonemic categories. The slopes and y-intercepts describe the degree of coarticulation and relational differences for place of articulation. Stop consonant-vowel productions of five full term and five preterm infants were analyzed from 8 to 17 months. The results revealed that slopes for place of articulation were significantly different, with the exception of [b] and [d]. Although preterm and full term group differences were not significant, Figure D-11 illustrates that full term infants tend to be more similar to adult coarticulation patterns than the preterm infants. Descriptive comparisons of the two groups indicated that full term infants produced more stop CV productions than preterm infants; preterm infants varied less in their coarticulation of CV syllables than full term infants; and that both groups' slope values indicate that place of articulation was less contrastive than that observed in adult or older children's slopes. In conclusion, the results of this study support the use of the locus equation metric to describe early CV productions. [Work supported by NIH.]

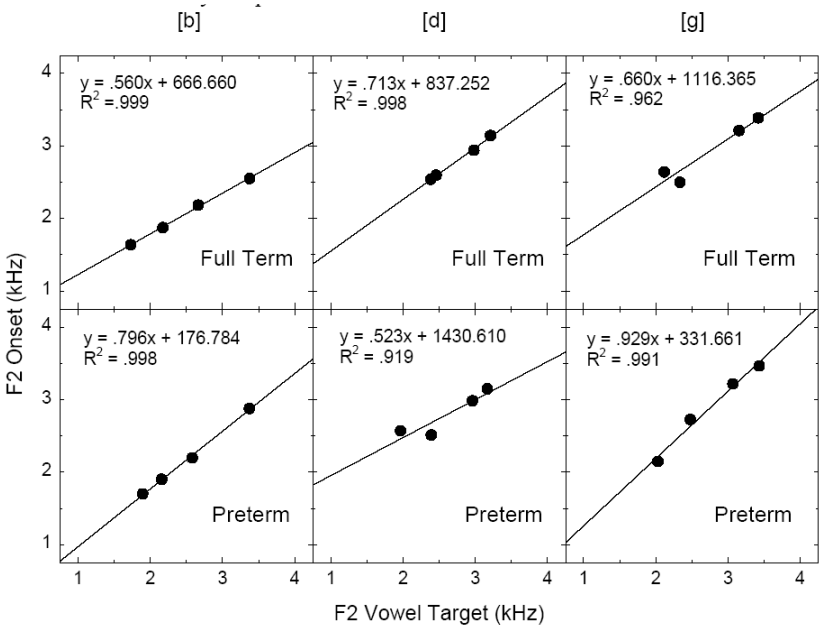

Figure D-11. Group mean locus equations for the full term infants (upper panels) and preterm infants (lower panels). Place of articulation is [b] (left panels), [d] (middle panels), and [g] (right panels). Slopes, Y-intercepts, and R^2 values are indicated for each regression scatterplot. Ohde & Gibson.

Ohde, R.N., and Hatfield, B.E. (In preparation). The development of stop consonant place of articulation in preadolescent children.

Locus equations were investigated as a metric to reflect developmental changes across a broad age range for CV syllable productions. Sixty-four subjects in eight age groups (3-, 4-, 5-, 6-, 7-, 9-, 11-year-olds and adults) produced five repetitions of isolated CV syllables in random order comprised of [b d g] and the vowels [ɑ æ i u]. The second formant (F2) onset frequency and F2 vowel target frequency were measured for each CV syllable, and the relationships as locus equations were plotted for each stop consonant place of articulation. Locus equation statistics of slope, y-intercept, standard error of the estimate (SE), and R^2 were analyzed. Adult slopes were significantly different than most child group slopes (Figure D-12 illustrates the locus equations for the [g] place of articulation). Slopes for place of articulation were significantly different with the exception of [d] and [g]-palatal. Analysis of y-intercepts revealed a significant main effect for place of articulation and a significant place X age interaction. Analysis of standard error of estimate and R^2 showed significant main effects for age and place of articulation. In summary, the SE results indicated that children 5-years and younger were more variable in production than older children and adults. The findings for slope generally indicated a greater degree of coarticulation in children than adults. [Work supported by NIH grant DC00464.]

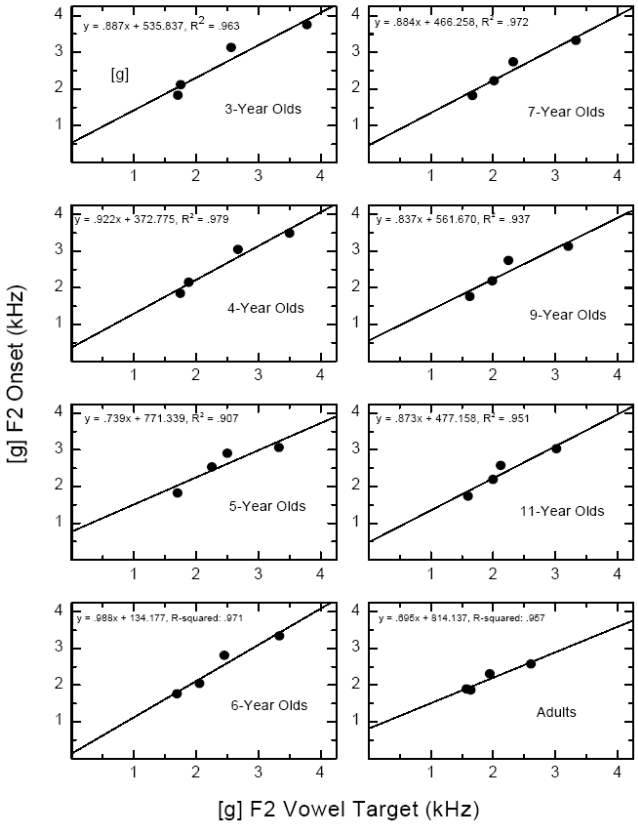

Figure D-12. Group mean locus equations for the [g] place of articulation. Slope, Y-intercept, and R-squared values are indicated for each regression scatterplot. Ohde & Hatfield.

Ohde, R.N., Hicks, C.D., **Ashmead, D.,** and Alaskary, H.A. (In preparation). Adult perception of the emerging vocant in toddlers.

In perceiving vowels, adults appear to use both "dynamic" formant transition cues and "static" formant target cues. The importance of these cues in perception is based on vowels produced by adults. According to theory, "dynamic" formant transition cues may be salient in adults' perception of vowels. However, the perceptual role of "dynamic" and "static" cues is unclear for vowel-like sounds (vocants) produced by vocal tracts much different from the adult vocal tract. For example, the early vocant productions by infants tend to emphasize "static" cues rather than "dynamic cues". Thus, it is unclear which cues are used by adults in the perception of infant vocants. If adults weight "dynamic" cues more than "static" cues, then poor identification of vocants would be predicted in the early infant productions. The purpose of this study is to examine adults' perceptual weighting of "dynamic" and "static" cues in the perception of infant vocants. In addition, the study will examine if an adult's ability to utilize "dynamic" versus "static" cues changes as a function of child age. The productions of three infants were recorded over a period of time from 9 months of age to 14 months of age. Vowels of the three infants judged by a panel of listeners to be of appropriate quality were edited into the following stimulus conditions: 1) full CV stimulus, 2) vocant target, 3) vocant transition, and 4) vocant target equivalent in duration to vocant transition. Ten adults phonetically transcribe the vocant stimulus conditions of the three infants. As illustrated in Figure D-13, segment 2 for both the correct response and primary pattern response contributed most to the identification of vowels produced by infants. Segment 2 contained the static

‘target” cues and supports the theory that the static not the dynamic information contributes to the accurate identification of vowels produced by infants.

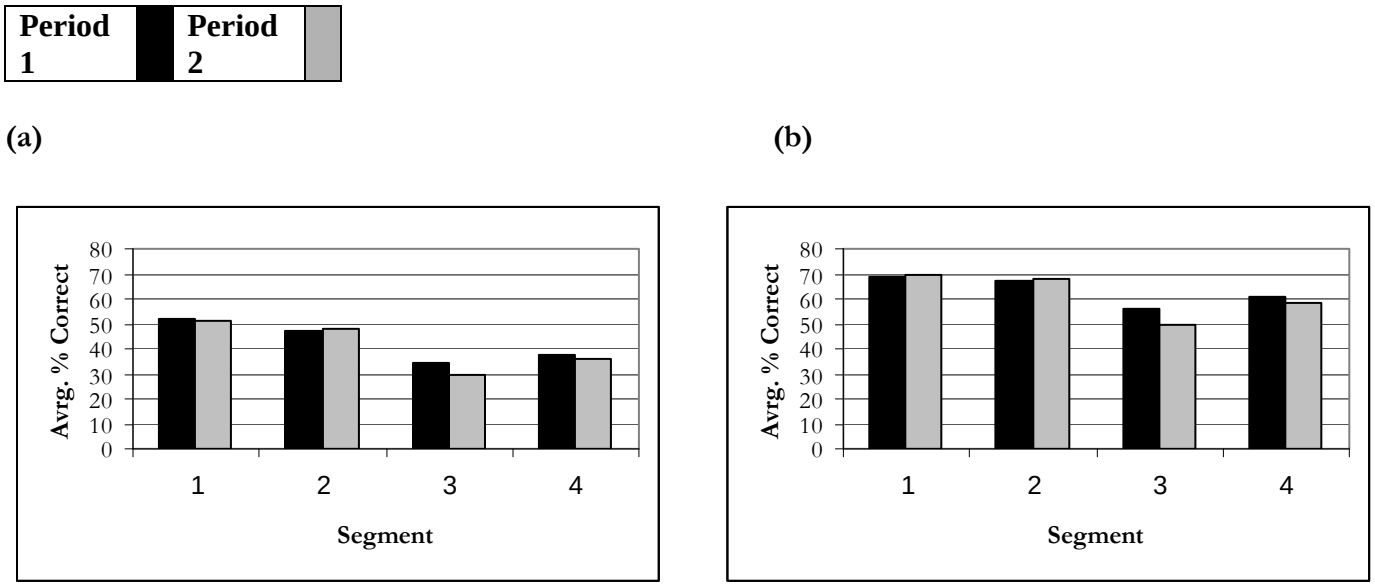

Figure D-13. All Speaker Averages for (a) Correct Responses and (b) Primary Pattern Responses for Period 1 and 2. Segment (1) represents the Full Length Syllable, (2) is the Full Vowel Portion, (3) is the Burst + Transition, and (4) is the Vowel Length that is Equivalent to Transition Length. Ohde *et al.*

Ohde, R.N. & McClure, M.J. (In preparation). The development of coarticulatory and segmental properties in nasal+vowel syllables.

The vowel transitions and nasal murmurs of nasal consonant + vowel (CV) syllables were acoustically analyzed in order to identify developmental changes in coarticulatory and segmental properties of speech. Thirty-two subjects in four age groups (3-, 5-, 7-year-olds and adults) produced five repetitions of CV syllables comprised of the nasal consonants [m n] and the vowels [i æ u ɑ]. The onset and target frequencies of the second formant (F2) of the vowel were measured for each CV syllable, and the resulting data points were plotted as locus equation regression lines to assess coarticulated properties. The second resonance peak (N2) of the nasal murmur was analyzed to assess segmental properties. The results revealed that coarticulation and variability in production decreased throughout development. As shown in Figure D-14, the N2 segmental property differentiated between [m] and [n] in children but not in adults. A measure of transition rate did not reveal extensive developmental change, but distinguished between places of articulation from a young age. These findings for nasal+vowel syllables show that both coarticulatory and segmental properties are different between children and adults. For children, there is minimum and maximum production distinction in coarticulatory and segmental properties, respectively, for place of articulation of nasals. [Work supported by NIH grant DC00464.]

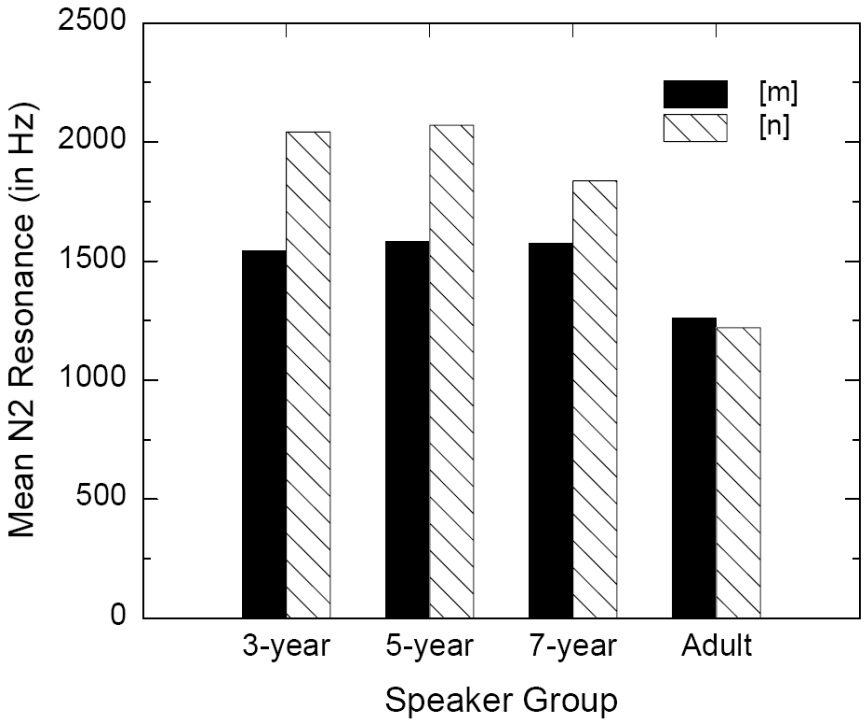

Figure D-14. Mean second nasal resonance (N2) for [m] and [n] across speaker groups. Ohde & McClure.

Ohde, R.N., and Vause, N.L. (In preparation). The level of perceptual integration of place of articulation of nasal consonants from short duration segments.

Recent findings [Ohde and Perry, *J. Acoust. Soc. Am*. 96, 1303-1313 (1994); Ohde and Ochs, *J. Acoust. Soc. Am.* 100, 2486-2499 (1996)] indicate that a peripheral mechanism may be involved in processing spectral discontinuities from the nasal murmur to vowel onset. The purpose of the current study was to assess the level of perceptual integration of nasal consonants. The speech sample was comprised of CV syllables produced by a 3-year-old child and an adult female and male, and consisted of either [m] or [n] in the context of four vowels [i æ u *a*]. Thirteen adults identified the place of articulation of the nasal before and after the insertion of periods of silence ranging from 0 to 1000 ms between murmur and vowel transition segments of varying duration. In the experimental conditions, the murmur and the vowel were split and presented to different ears. The major findings, as illustrated in Figure D-15, were as follows: 1. Perceptual integration was significantly greater for the murmur + transition presented monaurally with a 0 ms gap duration than the comparable split channel condition; and 2. Across the split channel conditions, identification of place of articulation of the nasal was near chance level (50%). The results support the conclusion that a major component of the observed perceptual integration effect is based on a peripheral mechanism.

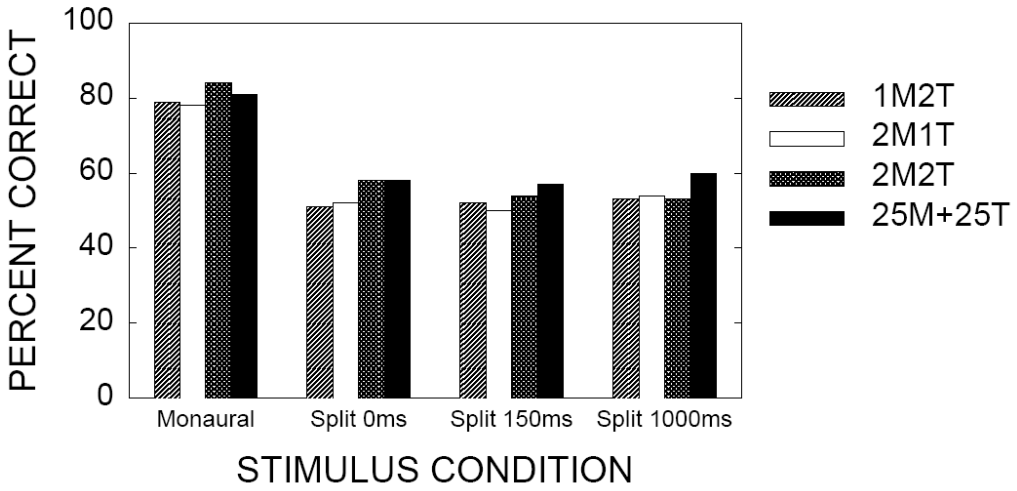

Figure D-15. Mean identification of nasal place of articulation for the adult male speaker as a function of stimulus presentation condition (Monaural: both stimuli to one ear; Split 0 ms: stimuli to different ears with 0 ms delay; Split 150 ms: stimuli to different ears with a 150 ms delay; Split 1000 ms: stimuli to different ears with a 1000 ms delay), and short duration stimuli (1M2T: one murmur + two transition periods; 2M1T: two murmur + one transition period; 2M2T: two murmur + two transition periods; 25M+25T: 25 ms murmur + 25 ms transition). Ohde & Vause.

Rosenthal, J.F., **Spencer, E.J.,** and **Schuele, C.M.** (November, 2007). Preschool children's responses patterns on the TEGI past tense probe. Poster presented to Annual Conference of American Speech, Language and Hearing Association, Boston, Massachusetts.

This study examined the response patterns of typical preschool children (n = 29) on the past tense probe of the Test of Early Grammatical Impairment. Children accurately marked past tense on regular verbs more frequently than irregular verbs but marked finiteness with equal frequency for regular and irregular verbs. Patterns of performance with respect to the features of the target verb (e.g., past-tense allomorph) and clinical implications will be discussed. Funding: NIH/NIDCD RO3 DC 007329 (PI: Schuele).

Schuele, C.M., **Barako Arndt, K**., **Spencer, E.J.** and **Guillot, K.M.** (November, 2007). Preschoolers production of complex syntax in elicited tasks. Poster presented to Annual Conference of American Speech, Language and Hearing Association, Boston, Massachusetts.

There has been limited investigation of complex syntax development in typically developing children and children with SLI. The purpose of this study was to explore the production of complex syntax using elicited tasks with typical preschoolers (n = 30). Elicited complex syntax tasks targeted five structures: infinitives, full propositional complements, wh-complements, and subject and object relatives. In the analysis of responses, of interest was the number of children within each age group who produced each target structure and the extent to which individual children produced multiple complex types. Additionally, analysis focused on the grammatical accuracy of the various complex syntax types. Infinitives and full propositional complements were more easily produced than the other complex types. Few children had difficulty with the grammatical structure of the complex syntax structures. Four-year-olds were more successful at producing complex syntax than three-year-olds. Funding: NIH/NIDCD RO3 DC 007329 (PI: Schuele).

Schuele, C.M., **Barako Arndt, K.**, **Spencer, E.J.**, and **Guillot, K.M.** (June, 2007). Preschool children's production of infinitives, relative clauses, and clausal complements in elicited language tasks. Poster presented to the Annual Symposium on Research in Child Language Disorders, Madison, Wisconsin.

There has been limited investigation of complex syntax development in typically developing children and children with SLI. The purpose of this study was to explore the production of complex syntax using elicited tasks with typical preschoolers (n = 30). Elicited complex syntax tasks targeted five structures: infinitives, full propositional complements, wh complements, and subject and object relatives. In the analysis of responses, of interest was the number of children within each age group who produced each target structure and the extent to which individual children produced multiple complex types. Additionally, analysis focused on the grammatical accuracy of the various complex syntax types. Infinitives and full propositional complements were more easily produced than the other complex types. Few children had difficulty with the grammatical structure of the complex syntax structures. Four-year-olds were more successful at producing complex syntax than three-year-olds. Funding: NIH/NIDCD RO3 DC 007329 (PI: Schuele)

Schuele, C. M., **Spencer, E.**, **Barako Arndt, K.**, and **Guillot, K.** (2007). Literacy and children with specific language impairment. *Seminars in Speech and Language*, 28(1), 35-47.

The purpose of this article is to summarize the literacy outcomes for children with specific language impairment and to consider principles and approaches for literacy intervention with preschool and early school-age children with language impairments. Initially, specific language impairment is defined and differentiated from nonspecific language impairment. In addressing intervention considerations, we first consider the application of best practice principles and then specifically focus on intervention with preschool children and intervention with early school-age children. Consideration of evidence-based treatment approaches is guided by the developmental literature and by the intervention literature.

Schuele, C.M., Spencer, E.J., Barako-Arndt, K., and **Guillot, K.M.** (2007). Literacy and children with specific language impairment. *Seminars in Speech and Language*, 29 (1), 35-47.

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Schuele, C. M., and Boudreau, D. (2008). Phonological awareness intervention: Beyond the basics. *Language, Speech, and Hearing Services in Schools*, 39, 3-20.

Purpose: The purpose of this article is to advance practitioners' knowledge base of best practices in phonological awareness intervention to facilitate the implementation of evidence- or research-based practices in everyday clinical practice. Although most speech-language pathologists (SLPs) have a basic knowledge of phonological awareness, this article provides additional information on the variables to consider in the design and implementation of phonological awareness intervention; access to this information has a clear impact on practitioners' efforts to move research to practice.

Method: We reviewed the relevant literature on the nature and development of phonological awareness and phonological awareness intervention to identify evidence-based intervention practices. We draw on clinical experience to supplement the research literature, particularly where the research literature provides limited direction.
Implications: SLPs have a unique contribution to make in school-based teams' efforts to facilitate literacy development in children, particularly children who are at risk for reading disability. Research provides much information to guide clinicians in the design and implementation of phonological awareness intervention.

Schuele, C. M., Justice, L., Cabell, S., Knighton, K., Kingery, B., & Lee, M. (2008). Field-based evaluation of two-tiered instruction for enhancing kindergarten phonological awareness. *Early Education and Development*, 19, 726-752.

This study reports on the outcomes of a multisite, two-tiered, response-to-intervention instructional model for delivering phonological awareness instruction and intervention to kindergartners. Fifty-seven kindergartners from 3 classrooms participated in a supplemental phonological awareness program, and 56 kindergartners from 3 classrooms received the prevailing school-adopted literacy curriculum. All children in the supplemental condition received supplemental classroom-based phonological awareness instruction in addition to the adopted literacy curriculum. At mid-year, 6 low literacy achievers were identified in each supplemental classroom (n = 18) to participate in an additional 12-week small-group intervention. The classroom-based supplemental curriculum did not produce statistically significant gains for typically achieving children on measures of letter-sound knowledge, word recognition, or developmental spelling. However, an add-on tier of supplemental instruction exerted a substantial advantage for low achieving children on a measure of developmental spelling. Results suggest that a 2-tiered intervention model provides an effective means for improving the literacy outcomes of low-achieving kindergarten children.

Spencer, E., **Schuele, C. M.**, **Guillot, K.**, and Lee, M. (2008). Phonemic awareness skill of speech-language pathologists and other educators. *Language, Speech, and Hearing Services in Schools*, 39, 512-520.

Purpose: Educators rely on sufficient knowledge and skill to provide effective phonemic awareness instruction, an important component of early literacy instruction, particularly for children who experience difficulty learning to read. The purpose of this study was to evaluate and compare the phonemic awareness skill of several groups of educators, including speech-language pathologists (SLPs; n = 160), kindergarten teachers (n = 109), first-grade teachers (n = 112), reading teachers (n = 100), and special education teachers (n = 60).
Method: Participants completed a paper–pencil measure of phonemic awareness skill that included 3 tasks. The measure was designed to assess sophisticated explicit phonemic awareness skill within a print context, representing an advanced skill level that has been deemed critical to teaching.
Results: SLPs demonstrated superior performance on the measure of phonemic awareness skill when compared to other educators (d = 1.54). The performance of reading and special education teachers was comparable to that of kindergarten and first-grade teachers. Orthographic knowledge had an adverse impact on the performance of all groups. However, SLPs were far more proficient than other educators at segmenting words that had a complex relationship between speech and print (e.g., box, use).
Clinical Implications: SLPs have relative expertise in phonemic awareness, yet their performance may not be proficient. Three recommendations are discussed: (a) Increase the phonemic awareness skill of all educators, (b) revise instructional materials to enhance educators' efforts to provide accurate and effective phonemic awareness instruction, and (c) include SLPs as members of the team responsible for phonemic awareness instruction and intervention.

Spencer, E.J., and **Schuele, C.M.** (2007). Phonological awareness intervention for lowest achieving kindergarten children. Poster presented to the Annual Symposium on Research in Child Language Disorders, Madison, Wisconsin (June) & Annual Conference of American Speech, Language and Hearing Association, Boston, Massachusetts (November).

Phonological awareness is one important aspect of early literacy instruction; intervention in phonological awareness may contribute to the prevention of reading difficulties. This study evaluated the effectiveness of a phonological awareness intervention in improving the skills of lowest achieving kindergarten children. In this field-based investigation, intensive and explicit intervention was provided to 87 kindergarten children, from 20 schools, who failed to make adequate progress by midyear. Treatment outcome was evaluated with a developmental spelling measure. The lowest achieving children who received the intervention demonstrated substantial benefit on posttest measures, although a gap remained between them and their adequately achieving peers. The intervention group had superior performance on multiple phoneme segmentation skills when compared to a non-intervention peer group. Results of the study provide evidence of an effective intervention targeting phonological awareness skills in children at high risk for reading disabilities. Results support a two-tier model of instruction and intervention in a school setting.

Spencer, E.J., **Schuele, C.M.**, and **Werfel, K.** (November, 2007). Kindergarten children's phonological awareness representation of consonant blends. Poster presented to Annual Conference of American Speech, Language and Hearing Association, Boston, Massachusetts.

This study examined the abilities of kindergarten children (n = 439) to represent initial consonant blends on a developmental spelling measure as an indication of emerging phonological awareness. Research indicates that segmentation of blends is a developmental accomplishment separate from the segmentation of singleton consonants. Children were assessed at the end of kindergarten as part of a field-based study of phonological awareness instruction and intervention. Kindergarten children demonstrated emerging ability to represent initial consonant blends. The ability to represent blends was related to representation of CVC words. When children were unable to represent a blend, the most common response was to represent only the initial sound. Implications for clinical practice and directions for future research are discussed.

Spencer, E.J., **Guillot, K.M.**, and **Schuele, C.M.** (November, 2007). Performance of undergraduate and graduate students on a measure of phonological awareness. Technical session presented to Annual Conference of American Speech, Language and Hearing Association, Boston, Massachusetts.

The purpose of this study was to evaluate phonological awareness in undergraduate and graduate students in speech-language pathology as compared to educators (special education teachers, reading teachers, kindergarten and first grade teachers, and SLPs). Participants completed a pencil-paper measure of phonological awareness. Results indicated that students had better phonological awareness than kindergarten and first grade teachers, special educators, and reading teachers but poorer phonological awareness than SLPs. As predicted, phonetics coursework positively predicted phonological awareness performance.

Spencer, E.J., and **Schuele, C.M**. (November, 2008). Reading growth in children with speech-language impairment: evidence from ECLS-K. Poster presented at the Head Start Research Conference, Washington, D.C. (June) and the Annual American Speech and Hearing Association Conference, Chicago, Illinois.

The purpose of the study was to describe reading growth between kindergarten and fifth grade for a large, nationally representative group of children who participated in the Early Childhood Longitudinal Study – Kindergarten cohort. Data were drawn from the Early Childhood Longitudinal Study (a public database), kindergarten class of 1998-99 (ECLS-K; National Center for Education Statistics, 2001). The ECLS-K is an ongoing study sponsored by the United States Department of Education and, thus far, has followed a large, nationally representative sample of children from kindergarten to fifth grade. Individual growth modeling was used to describe reading growth and evaluate speech-language impairment (S-LI) and early literacy skill as predictors. S-LI was a predictor of kindergarten literacy skill and S-LI and early literacy skill were predictors of reading growth. Children with S-LI begin kindergarten with poor literacy skills and demonstrate a slower rate of reading growth relative to peers with typical speech-language development.

Werfel, K., and **Schuele, C.M.** (November, 2008). Phonological awareness development: kindergarten children's segmentation and representation of consonant blends. Poster session presented to the Annual American Speech and Hearing Association Conference, Chicago, Illinois.

This study explored kindergarten children's phonological awareness by examining the segmentation and representation of initial (e.g., skate) and final (e.g., jump) consonant blends. In the course of development of phonological awareness, segmentation of blends is a distinct achievement from segmentation of singleton consonants. This aspect of phonological awareness is an understudied area. Children completed a 26 word developmental spelling measure three times in kindergarten (6 week intervals). Responses were analyzed for logical representation of speech sounds to describe developmental change and differential accuracy across blend types. Implications for practice are discussed.

E. Electrophysiology and Neuroscience

Anelli, R.M., and **Hood, L.J.** (March, 2009). Auditory steady-state responses using simultaneous multiple and intensity-ramped stimuli. Poster presented at the Annual Meeting of the America Auditory Society, Scottsdale, AZ.

Efficient and accurate estimation of frequency-specific hearing thresholds is essential for diagnosis and management of infants and children with hearing loss. Auditory steady-state responses (ASSR) provide objective physiologic threshold estimations and can be obtained with simultaneous presentation of multiple frequencies to both ears. The aim of this study was to compare ASSRs obtained with either two or four simultaneous stimuli and in discrete or ramped intensity paradigms. Response thresholds, noise levels and test time were assessed. Subjects were sixteen adults with normal hearing; five had participated in a previous study allowing assessment of test-retest reliability. Three stimulus conditions were compared using toneburst stimuli in an ASSR paradigm: two frequencies presented simultaneously at discrete intensities, four frequencies presented simultaneously at discrete intensities, and two simultaneous frequencies with intensity-ramping over a 40 dB range. Threshold levels for each stimulus condition were similar across frequencies, with the lowest variability and shortest test time occurring for the ramp stimulus. The results of this study show that efficiency in test time is increased while accuracy and test/re-test reliability are maintained, supporting the value of using a ramped-intensity stimuli in objective physiological testing. [Supported by NIH-NIDCD T35-DC008763]

Carriere, B.N., Royal, D.W., Perrault, T.J., Morrison, S.P., Vaughan, J.W., Stein, B.E., **Wallace, M.T.** (November, 2007). The effects of dark rearing on cortical multisensory development. Society for Neuroscience, 37th Annual Meeting, San Diego.

Cortical multisensory neurons in the anterior ectosylvian sulcus (AES) of the cat undergo a protracted period of maturation and functional development. Although multisensory neurons are evident in AES in relatively modest numbers as early as several weeks postnatal, integrative response properties typical of mature AES neurons appear gradually over a period of several months. This relatively lengthy maturational chronology suggests that early sensory experience may play a critical role in this developmental process. To test this, we eliminated all associations between visual and nonvisual stimuli by raising animals in the absence of visual experience. Once the animals reached adulthood, single unit extracellular recordings were then conducted at weekly intervals in the anesthetized and paralyzed preparation. Somewhat surprisingly, dark rearing had relatively little impact on the sensory distributions in AES, and a significant population (27%) of multisensory neurons remained after visual deprivation. In contrast, the integrative character of AES multisensory neurons was profoundly affected. This change is manifested in two significant ways. First, there is significant shift in the proportion of multisensory neurons that were modulated by, rather than overtly driven by, a stimulus in a second sensory modality (from 14% in normally-reared animals to 32%). More striking however was the shift in the proportion of these neurons that exhibited response depressions to stimulus combinations that would normally result in response enhancements, which now made up 73% of the population. Together, these results illustrate the importance of early sensory experience for the normal development of cortical multisensory processes. Furthermore, they argue that the lack of early visual experience results in a shift in the construction of these circuits such that inhibition plays a more important role.

Carriere, B.N., Royal, D.W., and **Wallace, M.T.** (2008). Spatial heterogeneity of cortical receptive fields and its impact on multisensory interactions, *Journal of Neurophysiology* 99, 2357-2368.

Investigations of multisensory processing at the level of the single neuron have illustrated the importance of the spatial and temporal relationship of the paired stimuli and their relative effectiveness in determining the product of the resultant interaction. Although these principles provide a good first-order description of the interactive process, they were derived by treating space, time and effectiveness as independent factors. In the cortex of the cat anterior ectosylvian sulcus (AES), previous work hinted that the spatial receptive field (SRF) architecture of multisensory neurons might play an important role in multisensory processing due to differences in the vigor of responses to identical stimuli placed at different locations within the SRF. In this study the impact of SRF architecture on cortical multisensory processing was investigated using semichronic single-unit electrophysiological experiments targeting a multisensory domain of the cat AES. The visual and auditory SRFs of AES multisensory neurons exhibited striking response heterogeneity, with SRF architecture appearing to play a major role in the multisensory interactions (Figure E-1). The deterministic role of SRF architecture was tightly coupled to the manner in which stimulus location modulated the responsiveness of the neuron. Thus, multisensory stimulus combinations at weakly effective locations within the SRF resulted in large (often superadditive) response enhancements, whereas combinations at more effective spatial locations resulted in smaller (additive/subadditive) interactions. These results provide important insights into the spatial organization and processing capabilities of cortical multisensory neurons; features that may provide important clues as to the functional roles played by this area in spatially-directed perceptual processes.

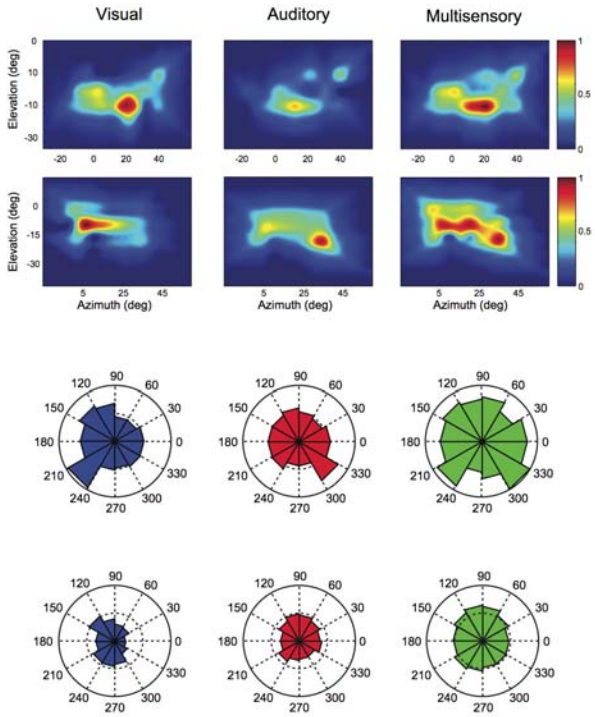

Figure E-1. Examples of response heterogeneity in the SRFs of cortical multisensory neurons. A. Plotted are the visual, auditory and multisensory SRFs for the region of receptive field overlap in an AES neuron. Each of the three representations has been normalized to the greatest evoked response, with the pseudocolor plots showing the relative activity scaled to this maxima. Below the SRFs are polar plots in which the center of the plot is the geometric center of the tested area of overlap. The magnitude of each wedge is proportional to the evoked response in that region of the receptive field, normalized across conditions. Carriere *et al.* (2008).

Carriere, B.N., Royal, D.W., Perrault, T.J., Morrison, S.P., Vaughan, J.W., Stein, B.E., and **Wallace, M.T.** (2007). Visual deprivation alters the development of cortical multisensory integration. *Journal of Neurophysiology* 98, 2858-2867.

It has recently been demonstrated that the maturation of normal multisensory circuits in the cortex of the cat takes place over an extended period of postnatal life. Such a finding suggests that the sensory experiences received during this time may play an important role in this developmental process. To test the necessity of sensory experience for normal cortical multisensory development, cats were raised in the absence of visual experience from birth until adulthood, effectively precluding all visual and visual-nonvisual multisensory experiences. As adults, semichronic single-unit recording experiments targeting the anterior ectosylvian sulcus (AES), a well defined multisensory cortical area in the cat, were initiated and continued at weekly intervals in anesthetized animals. Despite having very little impact on the overall sensory representations in AES, dark-rearing had a substantial impact on the integrative capabilities of multisensory AES neurons. A significant increase was seen in the proportion of multisensory neurons that were modulated by, rather than driven by, a second sensory modality. Perhaps more importantly, there was a dramatic shift in the percentage of these modulated neurons in which the pairing of weakly effective and spatially- and temporally-coincident stimuli resulted in response

depressions. In normally-reared animals such combinations typically give rise to robust response enhancements. These results illustrate the important role sensory experience plays in shaping the development of mature multisensory cortical circuits, and suggest that dark-rearing shifts the relative balance of excitation and inhibition in these circuits.

Delgado, R. E., Açıkgöz, N., **Hood, L.**, Özdamar, Ö., and Bohorquez. J. (2007) Fast infant audiogram determination using an intensity-ramping ASSR technique. International Evoked Response Audiometry Study Group, Slovenia.

A preliminary study demonstrating the acquisition of Auditory Steady State Responses (ASSR) from adults and children elicited using a linear Intensity-Ramping function is presented. In the typical ASSR testing technique, the stimulus intensity is maintained constant until a response is detected. Testing at individual intensities is repeated until the ASSR threshold is determined. With the present ASSR Intensity-Ramping technique, the stimulus intensity is changed during the one second stimulus presentation cycle. The stimulus may be composed of a single frequency, multiple frequencies or transients such as clicks or chirps presented to one or both ears simultaneously using unique modulation or repetition frequencies for each component and ear. When using a binaural multi-frequency stimulus with the ramping technique, the resulting data not only contains frequency response information but also frequency-specific threshold information in a single recording for both ears. Preliminary results from adults indicate a strong agreement with behavioral thresholds. The ASSR Intensity-Ramping technique is expected to significantly decrease testing time over currently available ASSR testing methods. [Research Supported by: NIH NIDCD SBIR Grant with Intelligent Hearing Systems Corp.]

Don, M., Elberling, C., and **Maloff, E.** (In press). Input and output compensation for the cochlear traveling wave delay in wide-band ABR recordings: Implications for small acoustic tumor detection. *Journal of the American Academy of Audiology*.

The Stacked ABR (Don et al., 1994) attempts at the output of the auditory periphery to compensate for the temporal dispersion of neural activation caused by the cochlear traveling wave in response to click stimulation. Compensation can also be made at the input by using a chirp stimulus (Dau et al., 2000; Elberling et al., 2007). Don et al. (1997; 2005b) demonstrated that the Stacked ABR is sensitive to small tumors that are often missed by standard ABR latency measures. Because a chirp stimulus requires only a single data acquisition run whereas the Stacked ABR requires six, we try to evaluate some indirect evidence justifying the use of a chirp for small tumor detection. We compared the sensitivity and specificity of different Stacked ABRs formed by aligning the derived-band ABRs according to (1) the individual's peak latencies, (2) the group mean latencies, and (3) the modeled latencies used to develop a chirp (Elberling et al., 2007). Results suggest that for tumor detection with a chosen sensitivity of 95%, a relatively high specificity of 85% may be achieved with a chirp. Thus, it appears worthwhile to explore the actual use of a chirp because significantly shorter test and analysis times might be possible.

Dowell, L.E., Foss-Feig, J.H., Kadivar, H., Stabin, L.J., Burnette, C.P., Esters, E.A., Woynaroski, T.G., Cascio, C.J., Stone, W.L., and **Wallace, M.T.** (July, 2008). An extended temporal window for multisensory integration in ASD, International Multisensory Research Forum, 9th Annual Meeting. Hamburg, Germany.

There has been much speculation that disruptions in multisensory processing may be important in autism. However, there is little empirical evidence to support this claim. In the current study we compared multisensory processing between children with typical development and ASD, with an emphasis on the

temporal window within which audiovisual stimuli are bound. We adapted three tasks which have been used in prior work to examine multisensory temporal processing (multisensory temporal order judgment [mTOJ], the flash-beep illusion [FB], and the McGurk), as well as tasks to assess unisensory temporal performance. There were no significant differences in unisensory temporal processing between the two groups. In contrast, children with ASD showed task performance improvements on the mTOJ over an interval two to three times larger than for typically developing children. Similarly, in the FB task illusory flashes were seen over a larger range of intervals for children with ASD. However, no differences were seen on the McGurk. Although our findings are preliminary, they suggest that there may be key differences in the time interval during which children with ASD integrate multisensory stimuli. These differences may ultimately provide a foundation upon which more effective diagnostic and interventional strategies may be developed.

Dowell, L.E., Foss-Feig, J.H., Kadivar, H., Stabin. L.J., Esters, E.A., Woynaroski, T.G., Burnette, C.P., Cascio, C.J., Stone, W.L., **Wallace, M.T.** (November, 2008). Changes in unisensory and multisensory temporal processing in autism spectrum disorders. Society for Neuroscience, 38th Annual Meeting, Washington, DC.

Autism spectrum disorders (ASD) form a complex class of developmental disorders which affect an individual's ability to communicate and function in social situations. ASD is also characterized by repetitive and rigid behavior. There has been much speculation that disruptions in sensory and multisensory processing may also be an important component of ASD. However, despite a wealth of anecdotal reports, there is little empirical evidence to support this claim. In the current study we compared unisensory and multisensory processing between children with typical development (TD) and ASD, with an emphasis on the temporal aspects of these processes. Of particular interest was defining the temporal "window" of multisensory integration, within which stimuli from different sensory modalities are "bound" into a unitary construct (as indexed by changes in performance). Participants (TD n=16, ASD n=8) completed a battery of temporal order judgment (TOJ) tasks that assessed auditory, visual and multisensory (i.e., auditory-visual) perceptual acuity. The multisensory TOJ task capitalized on prior work which has shown that task irrelevant auditory stimuli can improve performance (i.e., accuracy and response times) on the visual TOJ task if presented with a particular temporal structure (Morein-Zamir 2003; Hairston et al. 2006). Although we found a trend toward lower temporal acuity in the unisensory tasks for children with ASD, the largest effects were seen in multisensory TOJ performance, in which performance improvements were seen over a temporal interval two to three times longer than for TD children. Although preliminary, these findings suggest that there may be key differences in the temporal window within which children with ASD integrate multisensory stimuli. Such an extended binding window may play a key contributory role in the spectrum of deficits that characterize ASD. Furthermore, knowledge of these changes (and ultimately their neural bases) may ultimately provide a foundation upon which more effective diagnostic and interventional strategies may be developed.

Dowell, L.E., **Hillock, A.R.**, Rali, A.S., Stahl, J.M., Edge, C.T., Hairston, W.D., **Key, A.P.F.**, and **Wallace, M.T.** (November, 2007). An extended temporal window for multisensory integration in developmental dyslexia: Psychophysical and neuroimaging results," Society for Neuroscience, 37th Annual Meeting, San Diego.

As with space, multisensory cues presented in close temporal proximity will often be "bound" into a unitary event. Rather than being restricted to simultaneously presented stimuli, this multisensory synthesis has been shown to occur over a temporal window that can span several hundred milliseconds, and which likely reflects the underlying integrative operations of multisensory brain networks. In an effort to better define this window, task irrelevant auditory stimuli have been introduced into a visual

temporal order judgment (TOJ) task. These stimuli have been shown to improve task performance (i.e., accuracy and response times), but only if presented within a specific set of delays relative to the second visual target (100-250 ms; Morein-Zamir 2003; Hairston et al. 2006). Recently, we have adopted this task as a tool for examining differences in multisensory temporal processing in individuals with developmental dyslexia (Hairston et al. 2005). Although this work found that dyslexic subjects derive benefits on the multisensory TOJ task for temporal intervals longer than for normal reading subjects, it failed to adequately define the length of this extended temporal window. In the current study, we sought to better characterize this window and to probe the neural correlates of this altered temporal processing using fMRI and ERP. Dyslexic and normal reading control subjects first performed a visual TOJ task to determine their psychophysical thresholds, which were then used to examine the performance benefits (accuracy and response times) seen with the addition of task-irrelevant auditory cues for delays that extended out to 500 ms. Preliminary data suggests that the temporal window of multisensory binding for dyslexic subjects is approximately 400 ms, almost twice that of normal reading controls. In addition, there appears to be differential activation patterns in early multisensory brain regions (e.g., the occipito-parietal junction) in dyslexic subjects and that are associated with differences in task performance, suggesting alterations in prelinguistic multisensory circuits. Together, this work provides a clearer picture of the nature of the multisensory temporal processing deficits in dyslexia, and the possible neural substrates for these alterations

Fister, M.C., Krueger, J., Carriere, B.N., Royal, D.W., and **Wallace, M.T.** (November, 2008). Adult plasticity of spatiotemporal receptive fields of multisensory superior colliculus neurons following early visual deprivation. Society for Neuroscience, 38th Annual Meeting, Washington, DC.

A large population of superior colliculus (SC) neurons is known to be multisensory, responding to some combination of visual, auditory, and somatosensory information. Many of these multisensory neurons actively integrate their various sensory inputs, producing responses that differ markedly from the constituent unisensory responses. Previously, we demonstrated that multisensory neurons and multisensory integration in the SC appear and mature over a protracted period of postnatal life (Wallace and Stein 1997). More recently, we showed that the development of normal patterns of multisensory integration is critically dependent on sensory experience, in that visual deprivation early in life abolishes the integrative capacity of SC neurons (Wallace et al. 2004). Although these studies established the importance of early sensory experience in the creation of mature multisensory circuits, it remains unknown whether the reestablishment of normal sensory experience in adult life is sufficient to reverse these effects and restore multisensory integrative capacity. The current study was designed to test this hypothesis in cats that were reared in absolute darkness until adulthood and then returned to a normal housing environment as adults for an equivalent period of time (i.e., 6 mos. or longer). Single unit extracellular recordings targeted multisensory neurons in the deep SC, and analyses were focused on both conventional measures of multisensory integration and on more recently developed methods designed to characterize spatiotemporal receptive fields (STRF). Preliminary results suggest a limited degree of adult plasticity in this system, in that a small number of integrating neurons were found. Furthermore, STRF analyses revealed that the spatial architecture and temporal dynamics of multisensory SC neurons were far from normal in these animals, even after a substantial period of normal adult sensory experience. Taken together, these results not only provide additional support for the importance of early sensory experience in the establishment of normal multisensory processing architecture, but they also illustrate a limited degree of adult plasticity in these subcortical circuits.

Hackett, T. A., de La Mothe, L. A., Ulbert, I., Karmos, G., Smiley, J., & Schroeder, C. E. (2007). Multisensory convergence in auditory cortex, II. Thalamocortical connections of the caudal superior temporal plane. J Comp Neurol, 502(6), 924-952.

Recent studies of macaque monkey auditory cortex have revealed convergent auditory and somatosensory activity in the caudomedial area (CM) of the belt region. In the present study and its companion (Smiley et al., J. Comp. Neurol. [this issue]), neuroanatomical tracers were injected into CM and adjacent areas of the superior temporal plane to identify sources of auditory and somatosensory input to this region. Other than CM, target areas included: A1, caudolateral belt (CL), retroinsular (Ri), and temporal parietotemporal (Tpt). Cells labeled by injections of these areas were distributed mainly among the ventral (MGv), posterodorsal (MGpd), anterodorsal (MGad), and magnocellular (MGm) divisions of the medial geniculate complex (MGC) and several nuclei with established multisensory features: posterior (Po), supragenicular (Sg), limitans (Lim), and medial pulvinar (PM). The principal inputs of CM were MGad, MGv, and MGm, with secondary inputs from multisensory nuclei. The main inputs of CL were Po and MGpd, with secondary inputs from MGad, MGm, and multisensory nuclei. A1 was dominated by inputs from MGv and MGad, with light multisensory inputs. The input profile of Tpt closely resembled that of CL, but with reduced MGC inputs. Injections of Ri also involved CM but strongly favored MGm and multisensory nuclei, with secondary inputs from MGC and the inferior division (VPI) of the ventroposterior complex (VP). The results indicate that the thalamic inputs of areas in the caudal superior temporal plane arise mainly from the same nuclei, but in different proportions. Somatosensory inputs may reach CM and CL through MGm or the multisensory nuclei but not VP. See Figure E-2.

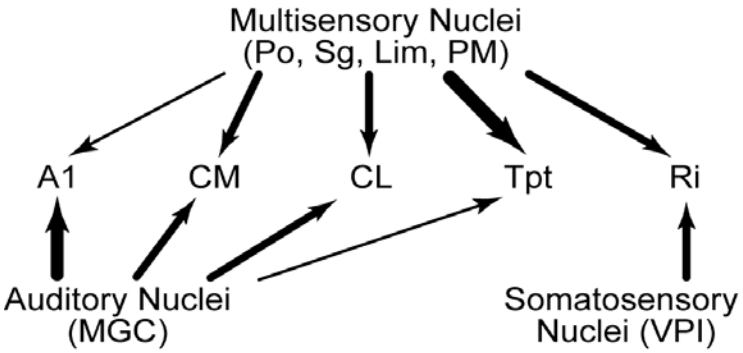

Figure E-2. Summary of thalamocortical inputs to A1, CM, CL, Tpt, and Ri in this study. Heavier arrows indicate denser projections. Auditory areas receive the densest inputs from the MGC and variable projections from the multisensory nuclei. Tpt receives the densest multisensory inputs and modest auditory projections. Ri has uncertain auditory inputs and stronger inputs from multisensory and somatosensory nuclei. Hackett *et al.* (2007)

Hackett, T. A., Smiley, J.F., Ulbert, I., Karmos, G., Lakatos, P., de la Mothe, L.A., Schroeder, C.E. (2007). Sources of somatosensory input to the caudal belt areas of auditory cortex. Perception, 36, 1419-1430.

The auditory cortex of nonhuman primates is comprised of a constellation of at least twelve interconnected areas distributed across three major regions on the superior temporal gyrus: core, belt, and parabelt. Individual areas are distinguished on the basis of unique profiles comprising architectonic features, thalamic and cortical connections, and neuron response properties. Recent demonstrations of convergent auditory ^ somatosensory interactions in the caudomedial (CM) and

caudolateral (CL) belt areas prompted us to pursue anatomical studies to identify the source(s) of somatic input to auditory cortex. Corticocortical and thalamocortical connections were revealed by injecting neuroanatomical tracers into CM, CL, and adjoining fields of marmoset (Callithrix jacchus jacchus) and macaque (Macaca mulatta) monkeys. In addition to auditory cortex, the cortical connections of CM and CL included somatosensory (retroinsular, Ri; granular insula, Ig) and multisensory areas (temporal parietal occipital, temporal parietal temporal). Thalamic inputs included the medial geniculate complex and several multisensory nuclei (supra- geniculate, posterior, limitans, medial pulvinar), but not the ventroposterior complex. Injections of the core (A1, R) and rostromedial areas of auditory cortex revealed sparse multisensory connections. The results suggest that areas Ri and Ig are the principle sources of somato- sensory input to the caudal belt, while multisensory regions of cortex and thalamus may also contribute. The present data add to growing evidence of multisensory convergence in cortical areas previously considered to be "unimodal," and also indicate that auditory cortical areas differ in this respect.

Hackett, T. A. (In press). Anatomical organization of the auditory cortex. *J Acad Audiol*.

The identification of areas that contribute to auditory processing in the human cerebral cortex has been the subject of sporadic investigation for more than one century. Several anatomical schemas have been advanced, but a standard model has not been adopted by researchers in the field. Most often, the results of functional imaging or electrophysiological studies involving auditory cortex are related to the cytoarchitectonic map of Brodmann (1909). Though useful as a guide and point of reference, this map has never been validated and appears to be incomplete. In recent years, renewed interest in the organization of auditory cortex has fostered numerous comparative studies in humans, nonhuman primates, and other mammalian species. From these efforts, common features of structural and functional organization have begun to emerge from which a working model of human auditory cortex can be derived. The results of those studies and the rudiments of the model are reviewed in this manuscript. See Figure E-3.

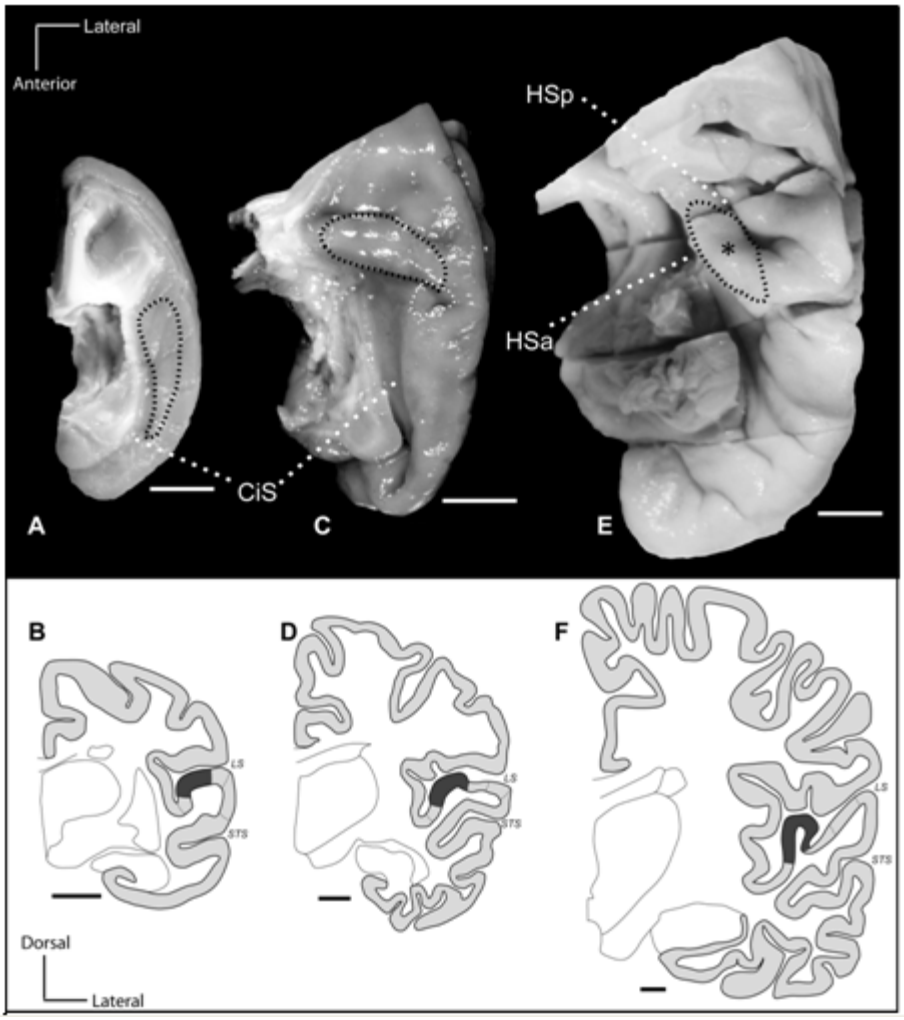

Figure E-3. Location of auditory cortex in the macaque monkey (A, B), chimpanzee (C, D), and human (E, F). *Top*, dorsal views of the superior temporal plane in each species. The location of the core region is outlined by a dashed ovoid. The location of the transverse temporal gyrus of Heschl (HG) and planum temporale (PT) are labeled in the chimpanzee and human specimens. Scale bars: 5 mm. *Bottom*, schematics coronal sections through auditory cortex. Dark shading denotes location of the core region. Dashed lines mark approximate locations of belt and parabelt areas on the superior temporal gyrus (STG), which is bound dorsally by the lateral sulcus (LS) and ventrally by the superior temporal sulcus (STS). CiS, circular sulcus; HSa, anterior Heshl's sulcus; HSp, posterior Heshl's sulcus. Scale bars: 5 mm. Hackett.

Hillock, A.R., and **Hood, L.J.** (March, 2008.) Noise effects on the speech-evoked auditory brainstem response and syllable identification. Presentation at the annual meeting of the American Auditory Society, Scottsdale, AZ.

The present study examined the influence of noise on brainstem responses to speech syllables and explored the relationship between physiological and behavioral measures of speech processing. Analyses revealed that brainstem response peaks display reduced amplitude and increased absolute latency with increasing noise; findings also indicated a differential effect of noise on response components. Interpeak

latency measures were stable across conditions. While accuracy scores on a nonsense syllable recognition measure also decreased with increasing noise, no significant relationship was observed between behavioral performance and peak amplitude measures. The implications of these findings and future directions are discussed. [Funding for travel and presentation of this project was provided by the NIH NIDCD Mentored Student Poster Travel Award.]

Hillock, A. R., Powers, A. R., Krueger, J, **Key, A. P. F.**, and **Wallace, M. T.** (July, 2008). Analysis of multisensory simultaneity perception in adults using event related potentials. Presentation at the International Multisensory Research Forum, Hamburg, Germany.

Psychophysical research in adults has defined a temporal window for binding auditory and visual stimuli into a unified perceptual construct. In an effort to gain insight into the neurophysiological correlates of this multisensory temporal binding window, perceptual reports and cortical event related potentials (ERPs) were collected in adults during a simultaneity judgment task. Objectively synchronous and asynchronous visual and auditory stimuli were presented in a randomly interleaved fashion and subjects were asked to report on their perception of simultaneity. In the asynchronous conditions, the onset of the visual stimulus preceded the onset of the auditory stimulus in 100 ms steps. Examination of perceptual responses revealed that the probability of reporting the stimuli as synchronous decreased rapidly across visual-auditory delays of 100 to 300 ms. Analysis of the auditory P1, N1, P2 complex relative to the tone pip revealed differences in the amplitude of responses to the veridical simultaneous condition relative to asynchronous conditions, and suggest a relationship between the perceptual binding of the multisensory stimuli and ERP responses. Ongoing work seeks to further elucidate the components of this ERP complex, and will focus on correlating the perceptual and physiological data in both the amplitude and latency domains.

Hillock, A.R., Powers, A.R., Krueger, J., **Key, A.P.F.**, and **Wallace, M.T.** (November, 2008). Electrophysiological correlates of auditory-visual perceptual simultaneity," Society for Neuroscience, 38th Annual Meeting, Washington, DC.

Prior research has shown that asynchronously presented auditory and visual stimuli will be judged as perceptually synchronous if the stimuli occur within a specific temporal window (Fujisaki, Shimojo, Kashino, & Nishida, 2004; Lewkowicz, 1996; McGrath & Summerfield, 1985; Vroomen, Keetels, de Gelder, & Bertelson, 2004). Despite the presumed utility of this multisensory temporal binding as a mechanism to fuse together causally-related stimuli (and consequently increase their perceptual salience), its neural basis remains unknown. The purpose of this work is to investigate the neurophysiological correlates of auditory-visual perceptual binding using event related potentials (ERPs). Participants performed a simultaneity judgment task while ERPs were recorded using a 128 electrode net. Objectively simultaneous and non-simultaneous auditory (tone pip) and visual (ring flash) stimuli were presented in a randomly interleaved fashion. In the asynchronous conditions, the onset of the visual stimulus preceded the onset of the auditory stimulus in 100 ms steps out to 500 ms. Perceptual judgments revealed that the probability of reporting the stimuli as synchronous decreased rapidly across auditory-visual delays from 100 to 300 ms. Analysis of the auditory P1, N1, P2 complex relative to the onset of the auditory cue revealed differences in the amplitude of responses to the veridical simultaneous condition relative to asynchronous conditions, suggesting a relationship between the perceptual binding of the multisensory stimuli and the amplitude of this ERP complex. Continuing research will seek to further clarify the relationship between perceptual and physiological responses, with the goal of better understanding the physiological generators of multisensory temporal binding.

Hillock, A.R., Powers, A.R., and **Wallace, M.T.** (July, 2009). Maturation of audiovisual simultaneity judgment. Poster to be presented at the 10th annual International Multisensory Research Forum, New York City.

Our world is inherently multisensory. Our ability to make assumptions about the relatedness of multisensory stimuli is largely based on their temporal and spatial relationships. Stimuli that are proximal in time and space are highly likely to be "bound" together by the brain and thus ascribed to a common external event. While the constraints to multisensory integration have been studied in human and animal models using both behavioral and physiological techniques, little is known about the temporal aspects of multisensory processing in children. Studies comparing behavioral responses of adults to gaze maintenance findings in infants have revealed developmental differences in the range of temporal asynchronies over which audiovisual stimuli are judged as simultaneous. Infants display a higher threshold for detecting interstimulus asynchrony; they bind more temporally disparate stimuli than adults (Lewkowicz, 1996). Previous research has also reported differences between children and adults in processing of coincident auditory-visual stimuli, but differences in the temporal aspects of multisensory integration have not been investigated between groups. In the current study, we compared the behavioral responses of 10 and 11 year-old children to those of adults on a simultaneity judgment measure. Findings revealed differences in the temporal profiles of multisensory integration between younger and older groups. Children were more likely to report stimuli as simultaneous at moderate and long stimulus onset asynchronies (-150 to -450 ms) in conditions where the auditory stimulus preceded the visual cue. Results will provide an empirical foundation for a broader developmental study of the chronology of multisensory temporal processing.

Hood, L.J., Golding, M., Mitchell, P., Smith, D, and Hartley, D, LI L. (In preparation.) Aging and suppression of otoacoustic emissions: The Blue Mountains Hearing Study.

Decreases in auditory efferent responses, assayed by measurement of the magnitude of suppression of transient-evoked otoacoustic emissions (TEOAEs) with age, are reported in some studies (Castor et al., 1994; Hood et al., 1997; Parthasarathy, 2001), but no change has been reported by others (Quaranta et al., 2001). To address this issue in a large number of subjects, we included measurement of TEOAE suppression in the Blue Mountains Hearing Study (BMHS) in Australia, a population-based survey of age-related hearing loss that commenced in 1997 (Mitchell et al.). Subjects were 2015 residents (75% of those eligible) over 50 years of age in two adjacent postal districts in the Blue Mountains region of Australia. Along with participating in eye and nutrition studies, subjects responded to comprehensive hearing and medical questionnaires and received extensive behavioral and physiological measures of peripheral and central auditory function. TEOAE suppression was tested in over 900 participants, excluding persons with significant hearing loss or lack of otoacoustic emissions. TEOAEs were obtained using 65 dB peak sound pressure linear clicks and contralateral broadband noise at 65-70 dB SPL. Two without noise and two with noise conditions were acquired. Signal-noise characteristics and amplitude and spectral characteristics of the OAEs and suppression were analyzed using the Kresge EchoMaster program. Results indicate decreases in suppression amplitude in older subjects. Characteristics of suppression, signal-noise analyses, and relationships to other patient characteristics and test results are discussed. [Supported by the Australian Department of Health and Family Services (RADGAC Grant), the National Health and Medical Research Council (Grants 974159, 991407), NIH NIDCD R01-DC03679, American Hearing Research Foundation, and Kam's Fund for Hearing Research.]

Hood, L.J., Hurley, A.E., Goforth, L., Bordelon, J., and Berlin, C. I. (In preparation.) Medial olivocochlear reflex characteristics to monaural and binaural activators vary with age.

Older individuals demonstrate reduced performance on a number of auditory tasks with particular difficulty when listening in noisy situations. Peripheral as well as central factors and afferent as well as efferent function may contribute to these difficulties. This study examined suppression of transient evoked otoacoustic emissions (TEOAEs) by binaural, ipsilateral and contralateral suppressor stimuli in subjects aged 10 to 80 years. TEOAEs were recorded using 80-microsec linear clicks presented at 65 dB peak sound pressure. Suppressors were broad band noise presented binaurally, ipsilaterally or contralaterally in a forward masking paradigm at an intensity of 60-65 dB SPL. Emissions recorded without noise were interleaved with noise conditions. Suppression was quantified by subtracting with noise from without noise conditions and examined as a function of time and frequency. The enhancement of suppression with a binaural suppressor over that for ipsilateral or contralateral suppressors decreased in older adults. These data suggest changes in response to binaural stimuli in older adults.
[Supported by the American Hearing Research Foundation, NIH NIDCD P01-00379, DOD DAMD 1793V3013, Kam's Fund for Hearing Research and the Louisiana Lions Eye Foundation.]

Hood, L.J., McCaslin, H., Maloff, E., and Delgado, R. (March, 2008). Physiologic threshold comparisons using ABR and ASSR techniques. Presented at American Auditory Society, Scottsdale, AZ.

Threshold estimation using auditory evoked potentials is a key component in quantifying frequency-specific hearing sensitivity in infants and young children. In this population, it is particularly critical to utilize approaches that yield sufficient information for differential diagnosis and management planning in an accurate and efficient manner. We compared physiologic responses obtained using toneburst auditory brainstem response (TB ABR), auditory steady-state response using discrete intensity levels and multiple frequencies (ASSR), and an ASSR technique using intensity-ramped stimuli (ASSR Ramp). Three specific studies were completed: comparison of intensity-ramped ASSR and ASSR thresholds in infants and children with normal hearing and hearing loss (n=40), comparison of ABR, ASSR, and intensity-ramped ASSR methods in adults with normal hearing (n=10), and comparison of single versus multiple simultaneous signals in adults with normal hearing (n=10). Stimuli were presented via earphones at frequencies of 0.5, 1, 2 and 4 kHz. Results indicate improved test efficiency with the intensity-ramped ASSR method. Intensity-ramped ASSR thresholds were an average of 4.5 dB lower for single than multiple simultaneous stimuli and were lower for ramped than discrete intensity methods. The results of this study support the value of new methods in physiologic testing and efforts to improve test efficiency and accuracy. [Supported by NIH NIDCD]

Hurley, A.E., **Hood, L.J.**, Cullen, J.K., Jr, and Cranford, J. (In press). Click ABR characteristics in children with temporal processing deficits. Journal of Educational Audiology.

Temporal processing deficits are one characteristic of a (central) auditory processing disorder [(C)APD]. Combining behavioral and electrophysiologic methods in the (C)APD battery is valuable. This investigation focuses on auditory brainstem response (ABR) measures in a group of children with specific temporal processing deficits and an age-matched control group. No significant differences in ABR waveform latency were found, but there were significant amplitude differences. Based on the results of this investigation, ABR testing using click stimuli with an interaural time delay (ITD) in the paradigm applied and population tested did not provide additional evidence of a temporal processing disorder.

Kajikawa, Y., de la Mothe, L. A., Blumell, S., Sterbing, S. J., d'Angelo, W. R., Camalier, C. R., & **Hackett, T. A.** (2008). Coding of FM sweep trains and twitter calls in area CM of marmoset auditory cortex. Hear Res, 239(1-2), 107-125.

The primate auditory cortex contains three interconnected regions (core, belt, parabelt), which are further subdivided into discreteareas. The caudomedial area (CM) is one of about seven areas in the belt region that has been the subject of recent anatomical and physiological studies conducted to define the functional organization of auditory cortex. The main goal of the present study was to examine temporal coding in area CM of marmoset monkeys using two related classes of acoustic stimuli: (1) marmoset twitter calls; and (2) frequency-modulated (FM) sweep trains modeled after the twitter call. The FM sweep trains were presented at repetition rates between 1 and 24 Hz, overlapping the natural phrase frequency of the twitter call (6–8 Hz). Multiunit recordings in CM revealed robust phaselocked responses to twitter calls and FM sweep trains. For the latter, phase-locking quantified by vector strength (VS) was best at repetition rates between 2 and 8 Hz, with a mean of about 5 Hz. Temporal response patterns were not strictly phase-locked, but exhibited dynamic features that varied with the repetition rate. See Figure E-4. To examine these properties, classification of the repetition rate from the temporal response pattern evoked by twitter calls and FM sweep trains was examined by Fisher's linear discrimination analysis (LDA). Response classification by LDA revealed that information was encoded not only by phase-locking, but also other components of the temporal response pattern. For FM sweep trains, classification was best for repetition rates from 2 to 8 Hz. Thus, the majority of neurons in CM can accurately encode the envelopes of temporally complex stimuli over the behaviorally-relevant range of the twitter call. This suggests that CM could be engaged in processing that requires relatively precise temporal envelope discrimination, and supports the hypothesis that CM is positioned at an early stage of processing in the auditory cortex of primates.

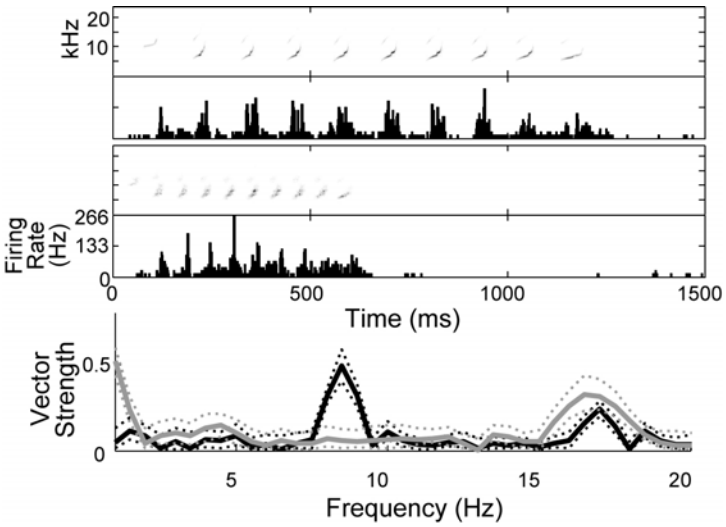

Figure E-4. Neuronal responses to marmoset monkey vocal calls. *Top panels*, sonogram of the twitter call (upper), and PSTH of response of one multiunit cluster (MU) (lower). *Middle panels*, sonogram of time compressed vocalization (upper) and PSTH of same MU (lower). Axes of top and middle figures are the same. *Bottom panels*, power spectra of the responses to normal call (black line) and compressed call (gray line). Dotted lines show upper and lower 95% confidence intervals of spectra, estimated by bootstrap sampling of 15 trials. Kajikawa *et al.* (2008).

Keeling, M.D., Calhoun, B.M., Kruger K, **Polley D.B.,** and Schreiner C.E (2008). Spectral integration plasticity in cat auditory cortex induced by perceptual training. *Experimental Brain Research*, 184(4), 492-509.

We investigated the ability of cats to discriminate differences between vowel-like spectra, assessed their discrimination ability over time, and compared spectral receptive fields in primary auditory cortex (AI) of trained and untrained cats. Animals were trained to discriminate changes in the spectral envelope of a broad-band harmonic complex in a 2-alternative forced choice procedure. The standard stimulus was an acoustic grating consisting of a harmonic complex with a sinusoidally modulated spectral envelope ("ripple spectrum"). The spacing of spectral peaks was conserved at 1, 2, or 2.66 peaks/octave (Figure E-5). Animals were trained to detect differences in the frequency location of energy peaks, corresponding to changes in the spectral envelope phase. Average discrimination thresholds improved continuously during the course of the testing from phase-shifts of 96 degrees at the beginning to 44 degrees after 4-6 months of training with a 1 ripple/octave spectral envelope. Responses of AI single units and small groups of neurons to pure tones and ripple spectra were modified during perceptual discrimination training with vowel-like ripple stimuli. The transfer function for spectral envelope frequencies narrowed and the tuning for pure tones sharpened significantly in discriminant versus naïve animals. By contrast, control animals that used the ripple spectra only in a lateralization task showed broader ripple transfer functions and narrower pure-tone tuning than naïve animals.

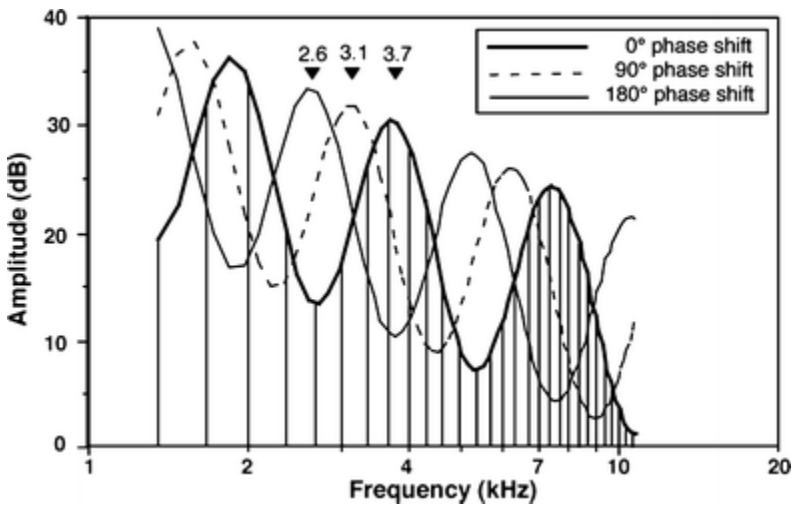

Figure E-5. See text. Keeling *et al.* (2008).

Key, A., Stone, W., and Williams, S.M. (Submitted). What do infants see in faces? ERP evidence of different roles of eyes and mouth for face processing in 9-month-old infants. *Infant and Child Development*.

The study examined whether face processing mechanisms in 9-month-old infants are differentially sensitive to changes in individual facial features (eyes vs. mouth) and whether sensitivity to such changes is related to infants' social and communicative skills. Infants viewed photographs of a smiling unfamiliar female face. On 30% of the trials, either the eyes or the mouth of that face were replaced by corresponding parts from a different female. Visual event-related potentials (ERPs) were recorded to examine face-sensitive brain responses. Results revealed that increased competence in expressive communication and interpersonal relationships was associated with a more mature response to faces, as reflected in a larger occipito-temporal N290 with shorter latency. Both eye and mouth changes were

detected, though infants derived different information from these features. Eye changes had greater impact on the face processing mechanisms and were not correlated with social or communication development, whereas mouth changes had minimal impact on the face processing mechanisms but were associated with levels of language and communication understanding

Key, A., Bradham, T., and **Porter, H**. (Submitted). Bilateral cochlear implants improve auditory processing in a pediatric unilateral implant user. *Journal of the American Academy of Audiology.*

The study examined auditory development in a child who received bilateral cochlear implants sequentially. Brain responses were recorded using two passive paradigms involving auditory perception (listening to speech syllables) and word-level processing (word-picture matching). Testing occurred prior to activation of the second cochlear implant and at 2, 4, and 6 months post-activation. The participant was a 6-year-old female child with the diagnosis of bilateral profound sensorineural hearing loss who received the first cochlear implant in her right ear at the age of 2 years, 4 months, underwent revision surgery for lack of progress in the same ear at age 3 years, 6 months and received a second cochlear implant in the left ear at 6 years, 8 months of age. Auditory stimuli were presented at 75 dB SPL(A) through a speaker above the participant's head with the cochlear implant(s) at typical user settings. Cortical responses were recorded from 128 electrodes and demonstrated progressive improvement in processing of individual syllables and words. The results demonstrate that sequential bilateral cochlear implantation contributes to improved auditory processing beyond the benefits of the single implant even in a user with extended period of deafness in the later-implanted ear.

Key, A., and Dykens, E. (Submitted). Multiple atypical neural mechanisms for contour construction in Williams Syndrome: ERP Evidence. *Neuropsychologia*.

Visuo-spatial construction abilities are a characteristic weakness in persons with Williams syndrome (WS). This study examined neural mechanisms of visuo-spatial construction in 16 adults with WS and 13 typical controls using an active contour completion task. Participants were asked to imagine connecting contour segments of a fragmented abstract figure and to compare the resulting image with a concurrently presented intact picture. ERP analysis revealed group differences in both early and late stages of perceptual processing. Compared to controls, participants with WS appeared to be consistently less able to select and implement the most optimal strategy, relying predominately on basic visual analysis. The results suggest that visuo-spatial difficulties in WS are associated with alterations in early perceptual processing as well as in advanced stages of visual analysis and construction.

Key, A., and Dykens, E. (2008). "Hungry Eyes": Visual processing of food images in adults with Prader-Willi syndrome. *Journal of Intellectual Disability Research*, 52(6), 536-546.

Background: Prader-Willi syndrome is a genetic disorder associated with intellectual disabilities, compulsivity, hyperphagia, and increased risks of life-threatening obesity. Food preferences in people with PWS are well-documented, but research has yet to focus on other properties of food in PWS, including composition and suitability for consumption. It is also unclear how food perceptions differ across the two major genetic subtypes of PWS.
Methods: This study examined neural responses to food stimuli in 17 adults with PWS, 9 with paternal deletions and 8 with maternal uniparental disomy (UPD), and in 9 age-matched typical controls. Visual ERPs were recorded in response to food images varying in food composition and suitability for consumption during a passive viewing paradigm.

Results: Group differences were observed for the N1 and P3 responses reflecting perceptual categorization and motivational relevance, respectively. The deletion group categorized food stimuli in terms of composition while the UPD group performed more similar to the controls and focused on the suitability of food for consumption. Individual differences in N1 amplitude correlated with BMI and scores on the Hyperphagia Questionnaire.
Conclusion: Differences are seen in how people with PWS due to deletion or UPD perceive visual food stimuli even within the first milliseconds of stimuli exposure. Implications are discussed for in-vivo food behaviors, and for future ERP or neuroimaging studies on hunger, satiety, and food perception in PWS.

Key, A., Ferguson, M., Molfese, D., Peach, K., Lehman, C., and Molfese V. (2007). Smoking during pregnancy affects speech discrimination ability in newborn infants. *Environmental Health Perspectives*, 115(4), 623-629.

Background: Tobacco smoking during pregnancy is known to adversely affect development of the central nervous system in babies of smoking mothers by restricting utero-placental blood flow and the amount of oxygen available to the fetus. Behavioral data associates maternal smoking with lower verbal scores and poorer performance on specific language/auditory tests.
Objectives: The current study examined the effects of maternal smoking during pregnancy on newborns' speech discrimination ability as measured by event-related potentials (ERPs).
Method: High-density ERPs were recorded within 48 hours of birth in healthy newborn infants of smoking (n=8) and nonsmoking (n=8) mothers. Participating infants were matched on sex, gestational age, birth weight, Apgar scores, mother's education and family income. Smoking during pregnancy was determined by parental self-report and medical records. ERPs were recorded in response to six CV syllables presented in random order with equal probability.
Results: Brainwaves of babies of non-smoking mothers were characterized by typical hemisphere asymmetries with larger amplitudes over the left hemisphere, especially over temporal regions. Further, infants of nonsmokers discriminated between greater number of syllables while the newborns of smokers began the discrimination process at least 150 ms later and differentiated between fewer stimuli.
Conclusions: Our findings indicate that prenatal exposure to tobacco smoke in otherwise healthy babies is linked with significant changes in brain physiology associated with basic perceptual skills that could place the infant at risk for later developmental problems.

Key, A., Stone W., Williams, S., Bradshaw, S., and Knoedelseder, K. (May, 2008). What do infants see in faces? Processing of facial features in infants at low and high risk for autism. Talk presented at the International Meeting For Autism Research, London, UK.

Background: Atypical attention to faces is one of characteristics of autism, and deficits in eye contact are common in infants later diagnosed with autism. While many studies examined general face processing in infants, few assessed the role of individual features.
Objective: The purpose of this study was to investigate whether infants siblings of children with autism process facial features differently from typical infants and whether attention to faces and their individual features is associated with infants' social and communicative behaviors.
Methods: Visual event-related potentials (ERPs) and eye tracking data were recorded in 20 infants with no family history of autism and 10 infant siblings of children with autism (age 9 months +/- 15 days). Infants viewed photographs of smiling unfamiliar female faces. On 30% of the trials, the eyes or the mouth of the standard face were replaced by corresponding parts from a different female face. Mothers completed Receptive and Expressive Communication, and Interpersonal Relationships subscales of VABS-II.

Results: Both eye and mouth changes were detected, but associated with distinct response patterns. In typical infants, eye changes affected the face processing mechanisms and were not correlated with social or communication development, whereas mouth changes had a minimal impact on the face processing mechanisms but correlated with levels of receptive and expressive communication. In infants at risk for autism, responses to mouth changes correlated with interpersonal scores while responses to eyes correlated with receptive communication.
Conclusion: Infants with low and high risk for autism may utilize similar brain mechanisms for face processing, however (1) they derive different information from eyes vs. mouth regions of a face, and (2) individual differences in processing of these features are related to social and communicative skills.

Key, A., Williams, S., and Dykens, E. (March, 2008). Adults with Williams syndrome demonstrate typical global processing. Talk presented at the 41th Annual Meeting of the Gatlinburg Conference on Research & Theory in Intellectual & Developmental Disabilities, San Diego, California.

Introduction: Williams syndrome (WS) is a genetic disorder characterized by visuo-spatial deficits. Previous behavioral studies frequently suggested local bias in perceptual processing as the main characteristic of visuospatial processing in persons with WS. The current study examined differences in brain activity associated with processing of local and global levels of visual stimuli in persons with WS as measured by event-related potentials (ERPs).
Methods: Visual ERPs were recorded from 22 adults (12 males) with WS (M=26.45+/-8.12 years) and a group of age and sex matched controls, using 128-electrode nets. Stimuli included Navon-like hierarchical stimuli (large letters made of smaller letters) and were presented using the oddball paradigm. The participants were asked to respond to the target letter by pressing a button. The target appeared at the global or local level equiprobably.
Results: Analysis of the behavioral responses revealed that participants in both groups demonstrated the expected global precedence effects as reflected in shorter RTs and higher accuracy for the targets presented at the global level. ERP analysis further demonstrated that in persons with WS, only global targets elicited frontal and centro-parietal oddball response, while in controls, both global and local targets were detected. Correlational analysis of the behavioral and ERP measures in persons with WS indicated positive association between frontal ERP response and reaction times for global targets (r=.56). ERP responses over frontal locations also correlated with accuracy scores for local targets (r=.453)
Discussion: Contrary to previous reports, when presented with hierarchical stimuli, participants with WS demonstrated a global precedence effect similar to that of the control participants. Interestingly, this effect was present in the absence of explicit instructions to direct their attention to any particular level of the stimulus, and thus can be interpreted as reflecting the dominant mode of visual analysis in persons with WS. These findings suggest that basic perceptual biases in persons with WS may be similar to those of typical participants and the observed deficits in visuospatial tasks are due to alterations at later stages of information processing. Lack of local target effects suggest reduced attention to smaller components of the stimuli or difficulty with analyzing the details once the overall identity of the stimulus has been established.

Key, A., Stone W., Williams, S., Bradshaw, S., & Knoedelseder, K. (February, 2008). Visual processing of facial features in infants at low and high risk for autism. Poster presented at the 35th Annual Meeting of the International Neuropsychological Society, Waikoloa, Hawaii.

Objective: The purpose of this project was to investigate whether infant siblings of children with autism who are at elevated risk for a diagnosis of autism process facial features differently from typical infants.
Participants and Methods: Visual event-related potentials (ERPs) and eye tracking data were recorded in 20 infants with no family history of autism and 8 infant siblings of children with autism, mean age 9

months +/- 15 days. Infants viewed photographs of smiling unfamiliar female faces. On 30% of the trials, the eyes or the mouth of the standard face were replaced by corresponding parts from a different female face to examine brain responses to changes in facial features.
Results: Condition effects were present for the peaks previously identified in infant studies as reflecting general face processing (N290, P400) but not for familiarity/novelty detection (Nc). A change in the eyes resulted in larger and faster N290 and smaller P400 peaks. In the high-risk sample, changes in the mouth rather than the eyes resulted in larger N290 component, while eyes change delayed N290 latency. Eye change resulted in increased number of fixations on eyes in all infants, however, low risk infants also increased duration of eye fixations, while high risk infants looked longer at the mouth.
Conclusion: Infants at low and high risk for autism utilized similar face processing mechanisms but differed in their preference for specific facial features. Because a reliable diagnosis of autism cannot be made at 9 months, our follow-up study will investigate whether observed altered patterns of face processing may be an early marker for autism.

Key, A., Porter, H., Bradham, T., and Mathiesen, S. (April, 2007). Event-related potentials in sequentially implanted children. Poster presented at the 11th International Conference in Cochlear Implants in Children, Charlotte, North Carolina.

The purpose of this study was to examine auditory and visual event related potentials (ERPs) using a 128-channel high-density sensor array in children who received bilateral cochlear implants sequentially. Administration of all tasks occurred before activation of the second cochlear implant and at 2, 4, and 6 months post activation of the second cochlear implant.Auditory ERPs were recorded in response to computer generated speech-sound stimuli. In addition, visual ERPs were recorded in response to a word-picture matching paradigm utilizing auditory presentation of words chosen from CNC word lists that either corresponded to (i.e. matched) or did not correspond to (i.e. mismatched) visual presentation of black-and-white drawings of common objects. Preliminary data showed similar auditory and visual ERP waveform morphology in children using sequential bilateral implants by 6 months post activation of a second, bilateral cochlear implant and children with normal hearing. In addition, changes in amplitude and latency of auditory and visual ERP components indicate both improved discrimination of consonant and vowel sounds over time and improved processing speed of spoken word recognition over time after activation of a second, bilateral cochlear implant.

Key, A., Williams, S., Mathiesen, S., Roof, E., Pantino, E., Kossler, R., Lerner, T., and Dykens, E. (February, 2007). Visual memory and spatial processing in young adults with Williams syndrome. Poster presented at the 34th Annual Meeting of the International Neuropsychological Society, Portland, Oregon.

Objective: Williams syndrome (WS) is a genetic disorder characterized in part by deficits in visuo-spatial processing. Previous behavioral findings noted abnormal performance on a variety of visual tasks. The current study examined differences in brain activity associated with visual memory and contour closure tasks in persons with WS as measured by event-related potentials (ERPs).
Participants and Methods: Visual ERPs were recorded from 9 adults with WS (age 17-32 yrs) and 9 age- and sex-matched controls. Stimuli included line drawings from the Motor Free Visual Perception Test. In the visual memory task, participants viewed a single picture (2000ms) and matched it to another image presented for 2500ms after a 3-sec delay. In the contour closure task, participants viewed pairs of stimuli consisting of complete and unfinished figures (2500ms) and decided whether the two drawings could be the same.
Results: In the memory task, controls demonstrated the typical “old/new” effect within 300-600ms. Participants with WS showed only an early recognition effect (150-190ms), but their accuracy was reasonable (76% correct). The contour task was more difficult (64% correct) and the ERPs indicated

stimulus evaluation beginning at least 50ms later and lasting up to 200ms longer than in controls.
Conclusion: The results suggest that performance differences in visuo-spatial tasks are due to altered perceptual mechanisms in WS. Increased reliance on early perceptual processes and difficulties with later stages may lead persons with WS to utilize simplified strategies. These strategies may be successful in simpler tasks but insufficient for more complex situations.

Key, A., Williams, S., Mathiesen, S., Roof, E., Pantino, E., Kossler, R. & Dykens, E. (February, 2007). "Are you going to eat this?": ERP indices of food perception in adults with Prader-Willi syndrome. Poster presented at the 34th Annual Meeting of the International Neuropsychological Society, Portland, Oregon.

Objective: Prader-Willi syndrome (PWS) is a genetic disorder characterized in part by unusual eating behaviors and risks of obesity. The current study was the first to examine differences in brain activity associated with evaluation of foods differing in suitability for consumption.
Participants and Methods: Visual ERPs were recorded from 16 adults with PWS (17-27 yrs) and 16 age- and sex-matched controls. Stimuli included color photographs of food items (single foods, proper and odd combinations, contaminated). The participants evaluated each stimulus regarding whether they would consider eating presented food.
Results: ERP analysis noted that food stimulus evaluation began as early as 50ms and continued through 600ms after stimulus onset. The two groups differed in the processing strategies as reflected in the types of discrimination and scalp topography. The controls consistently discriminated stimuli into "good"-"bad" categories based on visual properties (50-180ms) and cognitive evaluation (130-430ms). Participants with PWS grouped the stimuli into "single"-"combined" categories, did so quickly (50-180ms), and did not engage in any further classification.
Conclusion: Even in the absence of explicit responses, ERP results indicated that the two groups processed food stimuli differently. Unlike the controls, adults with PWS evaluated food exclusively in terms of quantity. This finding is especially interesting because persons with PWS typically can verbalize good/bad food choices but reported hypothalamus abnormalities resulting in impaired satiety signals may override their learned opinions about food. Further work needs to relate ERP findings to food preferences and real-life eating behaviors in those with PWS.

Krueger, J, Fister, M.C., Royal, D.W., Carriere, B.N., and **Wallace, M.T.** (November, 2008). A comparison of spatiotemporal receptive fields of multisensory superior colliculus neurons in awake and anesthetized cat," Society for Neuroscience, 38th Annual Meeting, Washington, DC.

The superior colliculus (SC) plays an integral role in orienting the eyes, pinna, and head to behaviorally-relevant stimulus events. In cat, more than 60% of deep SC neurons are multisensory, being influenced by stimuli from more than a single sensory modality. Previous work in anesthetized animals has shown that many of these multisensory neurons actively synthesize their various sensory inputs, producing integrated responses that differ markedly from the component unisensory responses. More recently, our laboratory has shown that these integrated responses are dependent upon the spatial receptive field architecture of multisensory neurons, and exhibit a temporal dynamism that is captured only when the spatiotemporal receptive fields (STRFs) are characterized. To date, these studies have been carried out in the anesthetized preparation because of the need for parametric stimulus control and because of the large number of stimulus conditions needed to define STRF organization with high resolution. The present study sought to extend this work by comparing STRF architecture, and the consequent impact of this organization on multisensory integration, between SC neurons in the awake and anesthetized cat. For the awake studies, animals were operantly conditioned to accept head restraint while fixating for food reward. Once a behavioral criterion was achieved, single unit recordings targeted multisensory neurons in the deeper layers of the SC. Unisensory and multisensory STRFs were derived and compared to one another,

to several predictive models, and between preparations. One of the most readily apparent difference between preparations was the relatively high level of spontaneous activity exhibited by neurons recorded in the awake condition. Analyses designed to characterize the temporal dynamics of the evoked responses (e.g., response latencies, peak firing rates, and discharge durations) revealed both similarities and differences between the anesthetized and awake preparations and across stimulus conditions. One intriguing suggestion from the preliminary data is that some multisensory influences may only be revealed in STRF plots of a subset of SC neurons that would have been categorized as unisensory using conventional metrics. These findings illustrate the significance of studying the behavior of SC neurons in awake cats and offer a tool to extend and possibly refine earlier descriptions of multisensory integration in the SC.

Lemons, C., **Key, A.**, Fuchs, D., Yoder, P., Fuchs, L., Compton, D., Williams, S., and Bouton, B. (Submitted). Predicting reading growth with event-related potentials: Thinking differently about indexing "responsiveness." *Journal of Learning Disabilities*.

The purpose of this study was to determine if event-related potential (ERP) data collected during three reading-related tasks: (a) Letter Sound Matching, (b) Nonword Rhyming, and (c) Nonword Reading, could be used to predict short-term reading growth on a curriculum-based measure of word identification fluency over 19 weeks in a sample of 29 first-grade children. Results indicate that ERP responses to the Letter Sound Matching task were predictive of reading change (r=.481, p=.013) and remained so after controlling for two previously validated behavioral predictors of reading, Rapid Letter Naming and Segmenting. ERP data for the other tasks were not correlated with reading change. The potential for cognitive neuroscience to enhance current methods of indexing responsiveness in a response-to-intervention (RTI) model is discussed.

Lemons, C., **Key, A.**, Fuchs, D., Fuchs, L., Williams, S., Mathiesen, S., Compton, D., & Bouton, B. (2007, March). Differentiating reading ability and predicting reading growth with event-related potentials. Poster presented at the Society for Research in Child Development, Boston, Massachusetts.

Objective: The purpose of this study was to investigate whether first grade students with differing levels of reading ability process printed letters and words in different ways and determine if post-instruction reading ability could be adequately predicted by pre-instruction event-related potentials (ERPs).
Method: Auditory ERPs for two tasks were recorded in 27 first-grade students from four metropolitan public schools (two Title I schools). ERPs were recorded using a 128-channel Geodesic sensor net while students performed two ERP tasks: a) Letter - Letter Sound Match, students were presented with single written letters followed by individual spoken letter sounds; b) Nonword Reading, students viewed 3-letter (CVC) strings, followed by a spoken nonword. In both tasks, students had to decide whether the spoken stimulus matched the visual stimulus. Standard achievement measures (Rapid Letter Naming, Segmentation, WRMT-R Word Attack, WRAT Reading, and CBM of word identification) used to determine reading ability were collected prior to the ERP session and again following 14 weeks of general education reading instruction. ERPs of advanced readers were expected to show greater discrimination between matching and mismatching stimuli and have shorter latencies than those of the poor readers, with average readers falling between these two groups.
Results: Significant reading group differences were found for both tasks and included early (100-200ms) effects associated with basic processing of physical properties of the stimuli and late effects (250-450ms) corresponding to more complex cognitive processing. Overall, group differences across both tasks could be attributed to processing strategy differences. Poor readers focused on early, basic stimulus characteristics (e.g., initial sound) and did not engage in more detailed processing of the stimuli as reflected in discrimination effects present only in the early time interval. Average readers demonstrated

more detailed processing (early and late discrimination effects) but their strategies relied heavily on familiarity/memory (reflected in activity over parietal and frontal sites), suggesting more controlled (less automatic) cognitive processing required for print-sound matching. Advanced readers processed the stimuli in the same time frame as the average group but relied more on auditory characteristics (reflected in activity over temporal and central sites), suggesting that they formed an auditory representation of the visual stimuli and matched the stimulus pairs based on sound. Additionally, the advanced group exercised greater precision in their response execution as reflected in additional later ERP effects (500+ms) and longer RTs. Pre-intervention ERP results also show some promise for predicting later reading ability. Conclusions: ERP results indicate that readers of differing reading abilities process and combine printed and spoken information significantly different. Advanced readers perform reading tasks with more efficiency and appear to approach such tasks more strategically. Results highlighting individual differences and the predictive utility of ERP data will be discussed.

Maloff, E., Grantham, D.W., Key, A., and **Ashmead, D.** (March, 2009). Brain activity underlying auditory motion perception in humans: An event-related potential study. Presented at the 2009 annual American Auditory Society conference, Scottsdale, Arizona (manuscript in process).

The neurological mechanisms responsible for auditory motion perception at the cortical level are not fully understood. Previous studies using event-related potentials and functional magnetic resonance imaging have attempted to identify the underlying brain regions involved in auditory motion perception, but the results among these are incongruent. The purpose of the current exploratory study was to investigate the event-related potential correlates to stationary and moving stimuli in normal hearing adult participants (n = 12). Principle component analysis was used to determine the spatial and temporal characteristics associated with these data. Spatial principle component analysis revealed considerable coordinated activity among electrodes surrounding and posterior to the vertex (spatial factors 1 and 2, respectively). Temporal principle component analysis revealed strongly coordinated activity in latency periods of approximately 350-850 ms (temporal factors 1 and 2) and also in periods of approximately 100-250 ms (temporal factors 3 and 4). Statistical results showed a significant main effect of condition in spatial factors 1 and 2 within temporal factors 1 and 2. Follow up analysis showed a significant difference between stationary and motion for spatial factor 2 within temporal factor 2. In addition, trends in these data showed differences between the stationary and motion conditions for spatial factors 1 and 2 within temporal factors 1 and 2. Future planned studies will explore whether recorded auditory responses are in fact due to the perception of motion or to the simple detection of change in the stimulus environment. Additional studies will examine these responses in adults with visual impairment or blindness.

Maloff, E.S., and **Hood, L.J.** (March, 2008). A comparison of chirp and click evoked auditory brainstem response. Presented at the 2008 annual American Auditory Society conference, Scottsdale, Arizona. (manuscript in process).

The Auditory Brainstem Response (ABR) with click stimuli is a powerful diagnostic tool used for neurological and hearing sensitivity measures. Although click evoked ABRs at high intensities allow sufficient neural synchronization, interpretation may be ambiguous at low intensity levels due to a lack of adequate auditory neural synchrony. Previously reported data from Dau and colleagues (Dau et al. 2000, Dau and Wegner, 2002) indicate that an ABR elicited by chirp stimuli at low intensities results in a response with better neural synchronization compared to responses from click stimuli in adults with normal hearing. In the current study we compared physiologic response thresholds obtained using click evoked ABR, chirp evoked ABR and behavioral measures in adults with normal hearing (n = 25) and sensorineural hearing loss (n = 25). Results revealed a significant difference between ABR thresholds obtained with chirp and click stimuli in both populations. In addition, overall behavioral thresholds were

more similar to chirp evoked ABR thresholds than to click evoked ABR thresholds in both populations. The results of this study indicate that chirp evoked ABR is an efficient method for estimating overall hearing thresholds in individuals with normal hearing and sensorineural hearing loss. [Funding for travel and presentation of this project was provided by the NIH NIDCD Mentored Student Poster Travel Award.]

McLean M.J., Engstrom S, Qinkun, Z., **Spankovich, C.**, and **Polley D.B**. (2008). Effects of static magnetic field on audiogenic seizures in black Swiss mice. *Epilepsy Research*, 80(2-3), 119-131.

Effects of a static magnetic field (SMF) with strong gradient components were studied in black Swiss mice. Exposure to SMF (100–220 mT, 15–40 T/m for 1 h) did not affect the threshold for detecting auditory brainstem responses. Serial seizures elevated the hearing threshold at some frequencies, but there was no difference between SMF-exposed and unexposed control mice. EEG changes were recorded during audiogenic seizures. Pretreatment with SMF prolonged seizure latency in response to stimulation with white noise of increasing intensity from 74 to 102 dBA (1 min interval between 2 and 4 dBA increments) without significant effects on seizure severity. Gender-related differences were not statistically significant. Stimulation with 10 min sound steps revealed prolongation of latency and reduction of seizure severity in SMF-exposed, but not unexposed, mice. Pretreatment with phenytoin (5 mg/kg) in combination with SMF had significantly greater effects on seizure latency and severity than either pretreatment alone. These findings indicate that the SMF studied here under different conditions elevated seizure threshold and had anticonvulsant properties in Black Swiss mice and increased the efficacy of a conventional anticonvulsant drug. See Figure E-6.

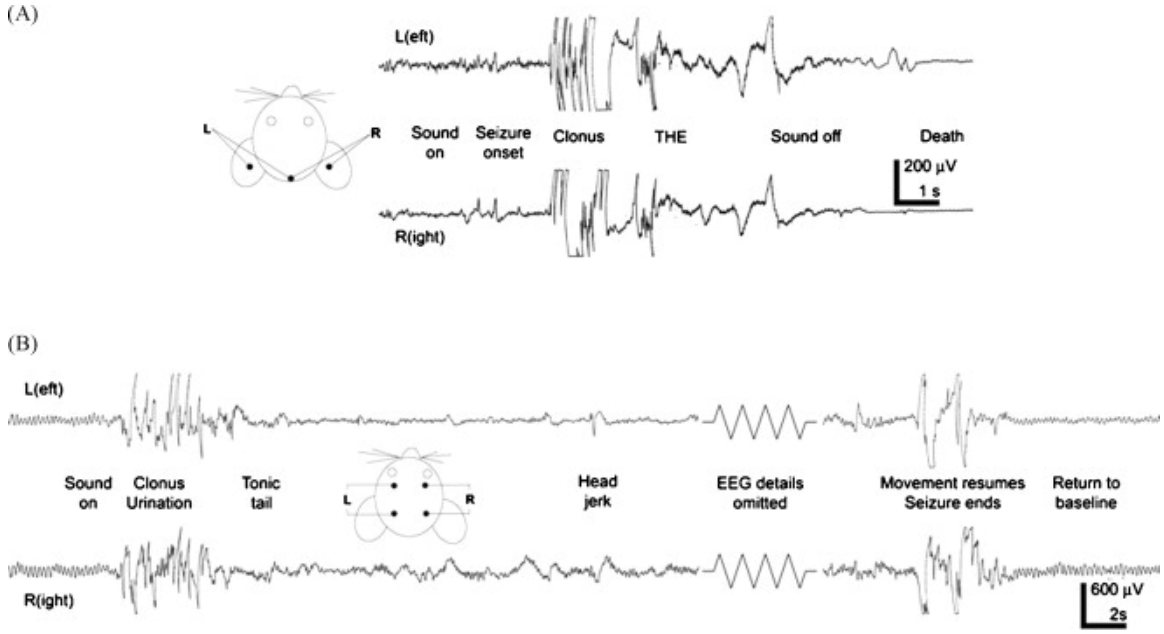

Figure E-6. See text. McLean *et al.* (2008).

Molfese, D.L., Molfese, V.J., Beswick, J., Jacobi-Vessels, J., Molfese, P.J., and **Key, A.** (In press). Dynamic links between emerging cognitive skills and brain processes. *Developmental Neuropsychology*.

The goal of the present study was to investigate whether advanced cognitive skills in one domain impact the neural processing of unrelated skills in a different cognitive domain. This question is related to the broader issue of how cognitive-neurodevelopment proceeds as different skills are mastered. To address this goal, event-related brain potentials (ERPs) were used to assess linkages between cognitive skills of preschool children as reflected in their performance on a pre-reading screening test (Get Ready To Read) and their neural responses while engaged in a geometric shape matching task. Sixteen children (10 males) participated in this study. The children ranged from 46 to 60 months (SD=4.36 months). ERPs were recorded using a 128-electrode high-density array while children attended to presentations of matched and mismatched shapes (triangles, circles or square). ERPs indicated that children with more advanced pre-reading skills discriminated between matched and mismatched shapes earlier than children with poorer pre-readings skills. The earlier discrimination effect observed in the advanced group was localized over the occipital electrode sites while in the Low Group such effects were present over frontal, parietal and occipital sites. Modeled MRIs of the ERP component sources identified differences in neural generators between the two groups. Both sets of findings support the hypothesis that processing in a poorer performing group is more distributed temporally and spatially across the scalp, and reflects the engagement more distributed brain regions. These findings are seen as support for a theory of neural-cognitive development that is advanced in the present paper.

Molfese, D.L., **Key, A.,** Rue, A., and Roman, A. (October, 2007). Developmental changes in word learning effects to auditorally named visual stimuli. Symposium on "How early is semantics? Electrophysiological correlates of semantic processing peaking earlier than the N400." 47th Annual Meeting of the Society for Psychophysiological Research (SPR), Savanah, Georgia.

This presentation reports on findings on brain auditory event-related potentials (ERPs) changes accompanying word learning in both infants and young adults. In both cases, ERPs were recorded to matching and mismatching names and objects before and after the training of labels for objects. Each trial involved presentation of a complex visual stimulus and its spoken name. Following training the number of correct responses for learned items increased greatly over chance levels. For adults, discrimination between learned labels for objects and unlearned as well as novel objects were noted for the P70, N100, and P300 components of the auditory ERPs with effects centered over mid-line and temporal electrode sites. The ERPs further differentiated between a familiarity response (late positive shift) and learning-specific changes (N2/P3 components). Infant auditory ERPs followed a similar pattern with word labeling effects occurring for an initial positive peak (~100 ms) as well as a positive peak mid-way through the epoch (~370 ms) and a late component at approximately 630 ms. Overall, the findings reinforce the notion that ERPs can be a useful tool for learning assessment and offer new insights in the study of individual differences associated with language acquisition and language processing.

Morrison, S.P., Carriere, B.N., Royal, D.W., Derderian, G.A., and **Wallace, M.T.** (November, 2007). Spatial and spatiotemporal architecture of multisensory receptive fields. Society for Neuroscience, 37th Annual Meeting, San Diego.

Two of the best-studied models for examining multisensory processing at the neural level are the superior colliculus (SC) and the cortex of the anterior ectosylvian sulcus (AES) of the cat. In each of these structures a large population of multisensory neurons is found, and both are characterized by a good spatial overlap of the different receptive fields of their multisensory neurons, suggesting that these subcortical and cortical areas play important roles in spatial processes. Multisensory SC and AES neurons

actively integrate their different sensory inputs, generating responses that differ substantially from the component unisensory responses. Multisensory responses in both structures follow a similar set of integrative principles that depend on the spatial and temporal relationships of the stimuli as well as their relative effectiveness. Although there are marked similarities between the SC and AES in regards to these global multisensory features, preliminary data suggests that the fine-grain spatial architecture of the receptive fields in the two structures may differ substantially. To examine this in more detail, we have conducted single unit extracellular recordings from multisensory SC and AES neurons of the anesthetized and paralyzed cat, and have mapped their spatial receptive fields (SRFs) to both unisensory and multisensory stimuli using a high density matrix of visual and auditory stimuli. When directly compared, although neurons in both structures show a significant overlap of their receptive field borders, the SRFs of AES neurons were significantly larger than for SC neurons. In addition, these AES SRFs were more heterogeneous in their spatial architecture, often showing multiple regions of widely varying response. Despite these differences, this SRF architecture appeared to be a major determinant of the multisensory interactions manifested in both populations of multisensory neurons. This determination appeared to be predicated not on spatial location per se, but rather on the way that spatial location modulates the responsiveness of the neuron. Thus, whereas multisensory stimulus combinations at weakly effective locations within the SRFs resulted in large (and often superadditive) response enhancements, combinations at more effective spatial locations resulted in smaller (additive/subadditive) interactions. Together, these results reveal both similarities and differences in the spatial organization and processing features of subcortical and cortical multisensory neurons; features that may provide important clues as to the functional roles played by these areas in spatially-directed behavioral and perceptual processes.

Polley, D.B., Read, H.L., Storace, D.A., and Merzenich, M.M. (2007). Multiparametric auditory receptive field organization across five cortical fields in the albino rat. *Journal of Neurophysiology* 97, 3621-3638.

The auditory cortex of the rat is becoming an increasingly popular model system for studies of experience-dependent receptive field plasticity. However, the relative position of various fields within the auditory core and the receptive field organization within each field have yet to be fully described in the normative case. In this study, the macro- and micro-organizational features of the auditory cortex were studied in pentobarbital-anesthetized adult rats with a combination of physiological and anatomical methods. Dense microelectrode mapping procedures were used to identify the relative position of five tonotopically organized fields within the auditory core: primary auditory cortex (AI), the posterior auditory field (PAF), the anterior auditory field (AAF), the ventral auditory field (VAF), and the suprarhinal auditory field (SRAF). AI and AAF both featured short-latency, sharply tuned responses with predominantly monotonic intensity-response functions. SRAF and PAF were both characterized by longer-latency, broadly tuned responses. VAF directly abutted the ventral boundary of AI but was almost exclusively composed of low-threshold nonmonotonic intensity-tuned responses. Dual injection of retrograde tracers into AI and VAF was used to demonstrate that the sources of thalamic input from the medial geniculate body to each area were essentially nonoverlapping. An analysis of receptive field parameters beyond characteristic frequency revealed independent spatially ordered representations for features related to spectral tuning, intensity tuning, and onset response properties in AI, AAF, VAF, and SRAF. These data demonstrate that despite its greatly reduced physical scale, the rat auditory cortex features a surprising degree of organizational complexity and detail. See Figure E-7.

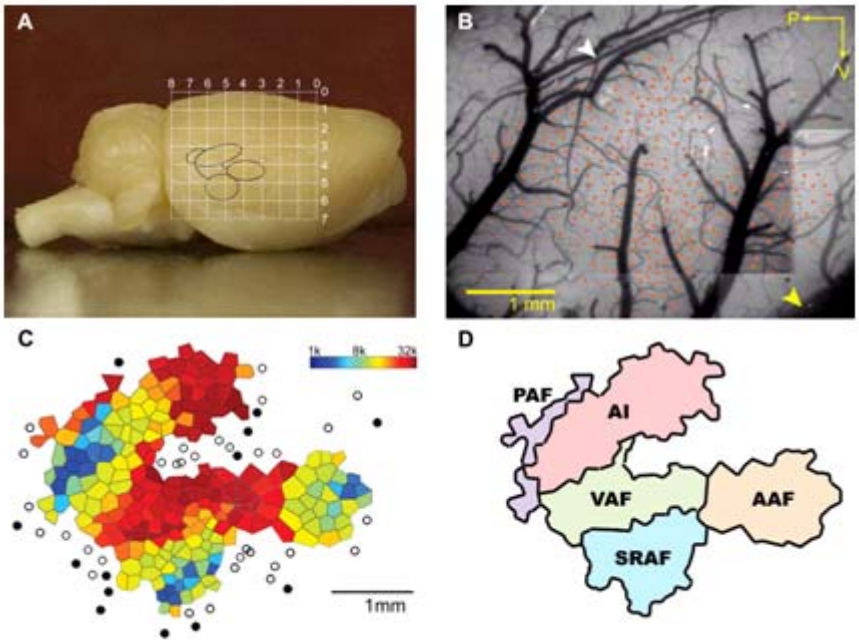

Figure E-7. See text. Polley *et al.* (2007).

Powers, A.R., **Hillock, A.R.**, and **Wallace, M.T.** (July, 2008). Perceptual training-induced narrowing of the multisensory temporal binding window. International Multisensory Research Forum, 9th Annual Meeting, Hamburg, Germany. Also presented at the Society for Neuroscience, 38th Annual Meeting, November, 2008, Washington, DC.

The brain's ability to bind incoming multisensory stimuli depends critically on their temporal structure. Specifically, there exists a window of time wherein multisensory stimuli are bound together, affecting perception and performance. Although recent evidence suggests that multisensory temporal processing is malleable in adults, no study has looked at whether this temporal window of integration can be narrowed. We used an audiovisual simultaneity task to determine the malleability of the temporal window's boundaries, subjecting 24 participants to a perceptual learning paradigm wherein feedback was given as to the correctness of their audiovisual simultaneity judgments. Results show that the temporal window was narrowed by 29% (from 291 to 177ms), the effect was stable for one week after training, and a similar effect was seen in subjects' susceptibility to the Flash-Beep illusion. Furthermore, the effects were specific to active training: subjects passively exposed to the identical stimulus set without feedback showed no performance improvements. This generalization indicates alteration of a common multisensory pathway and has strong implications for future manipulation of performance on more complex tasks. Given recent evidence for an expanded temporal window in neurodevelopmental disabilities such as dyslexia and autism, these efforts may lead to more effective diagnostic and remediation tools.

Powers, A.R., **Hillock, A.R.**, and **Wallace, M.T.** (Submitted). Perceptual training narrows the temporal window of multisensory binding, *Nature Neuroscience*.

The brain's ability to bind incoming auditory and visual stimuli depends critically on the temporal structure of this information. Specifically, there exists a temporal window of audiovisual integration within which stimuli are highly likely to be bound together and perceived as part of the same event. The plasticity of this window's boundaries was investigated using a perceptual learning paradigm in which participants were given feedback during an audiovisual simultaneity judgment task. The effects were rapid, robust, and long-lasting, seen as a 39% decrease in the temporal window's width after one hour of training that persisted for at least one week after training cessation (Figure E-8). Importantly, the effects generalized beyond the trained task, as exhibited by participants' altered susceptibility to a low-level audiovisual illusion. These results suggest a high degree of flexibility in multisensory temporal processing and have important implications for interventional strategies that may be used to ameliorate multisensory dysfunction.

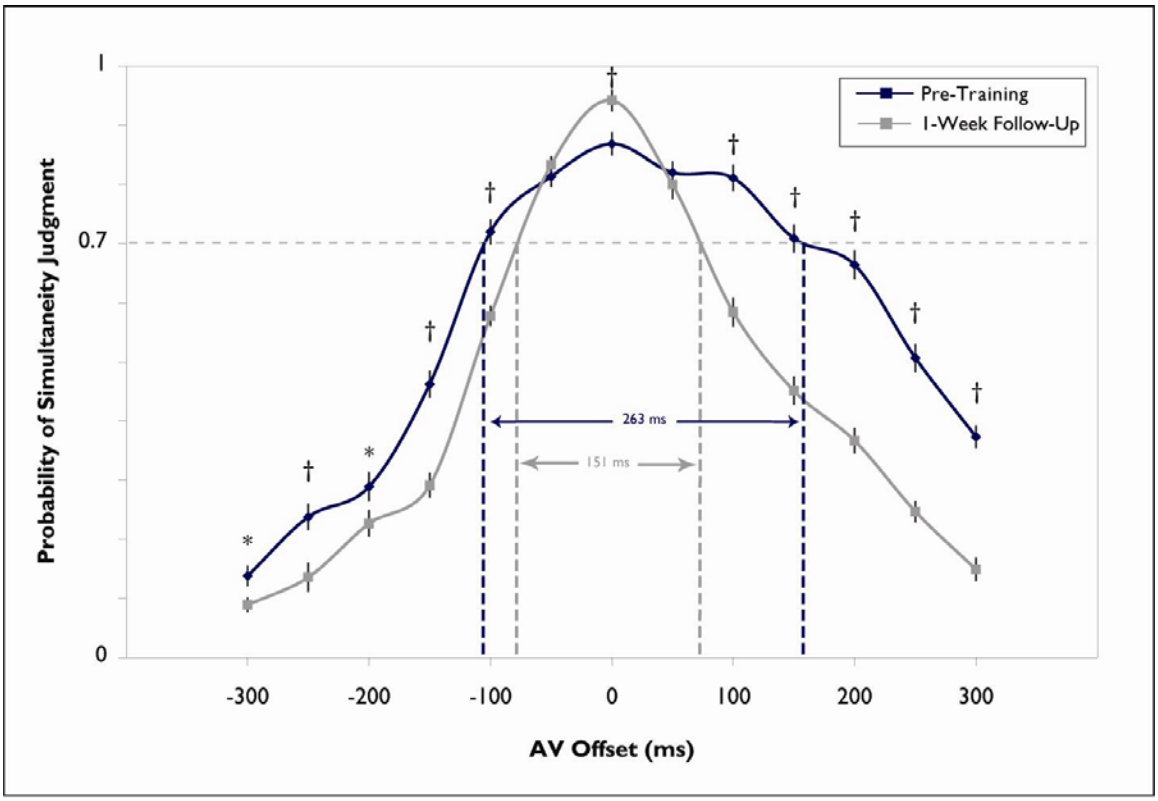

Figure E-8. Training-induced changes in the multisensory temporal window are stable. Probability distributions for 16 training subjects at baseline and one week after the end of training indicate retention of changes seen immediately after training and an increase in participants' likelihood to correctly identify the veridical simultaneous condition. Error bars indicate 1 SEM. * indicates p<0.05; # indicates p<0.01; † indicates p<0.001. Powers *et al.*

Rali, A.S., Dowell. L.E., Edge, C.T., Stahl, J.M., Stabin, L.J., and **Wallace, M.T.** (November, 2007). The effects of unattended multisensory information on complex task performance. Society for Neuroscience, 37th Annual Meeting. San Diego.

As for processing within the individual sensory systems, attention has been shown to strongly modulate multisensory processing. Much of this work has focused on the effects of endogenously- or exogenously-directed attention on simple tasks such as the detection and localization of targets. In contrast, much less is known about the influences of actively unattended stimuli on more complex tasks such as those performed in typical learning situations. To investigate this further, we designed a paradigm to examine whether unattended information both within and across sensory modalities would aid or interfere with the completion of a task within a sensory modality (i.e., vision). Participants were asked to view a sequential pattern of shapes and based on a prior stimulus set to choose the next shape in the sequence. During the "learning" phase of each trial the visual shapes were presented at fixation and were paired with an unattended visual (peripherally-presented color) and auditory (tone) stimulus. Each unattended stimulus was linked with a specific shape, and subjects were instructed that these stimuli were of no relevance to the task and to actively ignore them. During the test phase of each trial either the visual, auditory or paired stimuli were presented and subjects were asked to predict the next shape in the sequence. Participants' accuracy on each of the different trial types (including incongruent pairings and catch trials) was assessed in order to determine the effects of the task irrelevant stimuli on performance. Preliminary data suggests that the unattended visual and auditory information can aid in the completion of the visual pattern, and ongoing studies are attempting to dissect out the relative contributions of each. These data provide important insights into how unattended sensory information both within and across modalities can shape perceptual performance in complex tasks.

Rali, A.S., Dowell. L.E., Edge, C.T., Stabin, L.J., and **Wallace, M.T.** (July, 2008). The effects of unattended multisensory stimuli on a visual pattern completion task," International Multisensory Research Forum, 9th Annual Meeting, Hamburg, Germany.

Attention has been shown to strongly interact with both unisensory and multisensory processes. An emerging question of interest is whether unattended multisensory stimuli can be integrated in order to influence behavioral and/or perceptual performance. To investigate this question, we designed a paradigm to examine the impact of unattended information both within and across sensory modalities on a visual pattern completion task. Participants were asked to view a sequential pattern of shapes and to predict the next shape in the sequence. During the "learning" phase, the shapes were presented at fixation and were paired with an unattended visual (peripherally-presented color flash) and auditory (tone) stimulus. Each unattended stimulus was linked with a specific shape, and subjects were instructed to actively ignore them. During the test phase either the visual, auditory, or paired visual-auditory stimuli were presented, and subjects had to predict the next shape in the sequence. Participants' accuracy on each of the different trial types (including incongruent pairings) was assessed. Unattended unisensory stimuli and unattended congruent multisensory stimuli failed to significantly affect performance. In contrast, unattended incongruent multisensory stimuli significantly impaired performance, illustrating the capacity of unattended multisensory cues to interact with and shape behavior.

Royal, D.W., Carriere, B.N., Morrison, S.P., and **Wallace, M.T.** (2007). Spatiotemporal receptive field properties of superior colliculus multisensory neurons. Society for Neuroscience, 37th Annual Meeting, San Diego.

The superior colliculus (SC) plays an integral role in orienting the eyes, pinna, and head to behaviorally-relevant stimulus events. In cat, more than 60% of deep SC neurons are multisensory, responding to

some combination of visual, auditory, and somatosensory information. Previous work has shown that many of these multisensory neurons actively synthesize their various sensory inputs, producing integrated responses that differ markedly from the component unisensory responses. These studies have also established the importance of the spatial and temporal relationships of the combined stimuli, as well as their relative effectiveness, in the resultant multisensory interaction. Although these integrative principles provide a good first-order description of the operations performed by multisensory SC neurons, they fail to take into account the substantial spatial and temporal response heterogeneities inherent to SC receptive fields, and thus may offer only limited predictive insight into the nature of multisensory interactions. The present study was designed to extend earlier descriptions of multisensory integration in SC neurons and to characterize for the first time the spatiotemporal receptive fields (STRFs) of these neurons and the impact of this organization on multisensory interactions. To this end, standard extracellular single unit recordings were made from individual multisensory neurons in the SC of anesthetized and paralyzed cats while unisensory and multisensory stimuli were presented at a number of locations within and outside of the RF. Unisensory and multisensory STRFs were generated from collapsed spike density functions and their spatiotemporal patterns of activation were compared with a number of predictive models. In general, the unisensory STRFs of multisensory neurons had a large spatial extent but exhibited a surprisingly high degree of spatial correspondence and response heterogeneity. Multisensory STRFs could not be predicted based on a simple summation of these unisensory STRFS, and revealed changes in both the spatial and temporal domains attributable to the multisensory stimulus. These included shorter response latencies, greater peak firing rates and significantly longer discharge durations. Together, this work underscores the complex spatiotemporal dynamics of SC multisensory neurons, which is likely to play an important role in the encoding of salient stimulus events.

Royal, D.W., Carrier, B.N., and **Wallace, M.T.** (Submitted). Spatiotemporal architecture of cortical fields and its impact on multisensory interactions. *Experimental Brain Research.*

Recent electrophysiology studies have suggested that neuronal responses to multisensory stimuli may possess a unique temporal signature. To evaluate this temporal dynamism, unisensory and multisensory spatiotemporal receptive fields (STRFs) of neurons in the cortex of the cat anterior ectosylvian sulcus (AES) were constructed. Analyses revealed that the multisensory STRFs of these neurons differed significantly from the component unisensory STRFs and their linear summation. Most notably, multisensory responses were found to have higher peak firing rates, shorter response latencies, and longer discharge durations. More importantly, multisensory STRFs were characterized by two distinct temporal phases of enhanced integration that reflected the shorter response latencies and longer discharge durations. These findings further our understanding of the temporal architecture of cortical multisensory processing, and thus provide important insights into the possible functional role(s) played by multisensory cortex in spatially-directed perceptual processes.

Smiley, J. F., **Hackett, T. A.**, Ulbert, I., Karmas, G., Lakatos, P., Javitt, D. C., & Schroeder, C. E. (2007). Multisensory convergence in auditory cortex, I. Cortical connections of the caudal superior temporal plane in macaque monkeys. *J Comp Neurol*, 502(6), 894-923.

The caudal medial auditory area (CM) has anatomical and physiological features consistent with its role as a first-stage (or “belt”) auditory association cortex. It is also a site of multisensory convergence, with robust somatosensory and auditory responses. In this study, we investigated the cerebral cortical sources of somatosensory and auditory inputs to CM by injecting retrograde tracers in macaque monkeys. A companion paper describes the thalamic connections of CM (Hackett et al., J. Comp. Neurol. [this issue]). The likely cortical sources of somatosensory input to CM were the adjacent retroinsular cortex (area Ri) and granular insula (Ig). In addition, CM had reliable connections with areas Tpt and TPO, which are sites

of multisensory integration. CM also had topographic connections with other auditory areas. As expected, connections with adjacent caudal auditory areas were stronger than connections with rostral areas. Surprisingly, the connections with the core were concentrated along its medial side, suggesting that there may be a medial-lateral division of function within the core. Additional injections into caudal lateral auditory area (CL) and Tpt showed similar connections with Ri, Ig, and TPO. In contrast to CM injections, these lateral injections had inputs from parietal area 7a and had a preferential connection with the lateral (gyral) part of Tpt. Taken together, the findings indicate that CM may receive somatosensory input from nearby areas along the fundus of the lateral sulcus. The differential connections of CM compared with adjacent areas provide additional evidence for the functional specialization of the individual auditory belt areas.

Spankovich, C., Hood, L.J., Grantham D.W., and **Polley, D.B.** (2008). Application of frequency modulated chirp stimuli for rapid and sensitive ABR measurements in the rat. *Hearing Research* 245, 92-97.

Rodents have proven to be a useful model system to screen genes, ototoxic compounds and sound exposure protocols that may play a role in hearing loss. High-throughput screening depends upon a rapid and reliable functional assay for hearing loss. This study describes the use of a frequency modulated (FM) chirp stimulus as an alternative to the click to derive a rapid assessment of auditory brainstem response (ABR) threshold in the rodent. We designed a rising frequency A-chirp based upon the spatial mapping of preferred frequency along the rat basilar membrane to provide a more synchronous and equipotent input across the length of the cochlea. We observed that the ABR wave I and wave IV amplitudes evoked by the A-chirp were significantly greater than the click and that A-chirp minimum response thresholds were lower than the click (Figure E-9). Subsequent analyzes compared the efficacy of the A-chirp to linear, time-reversed and amplitude-reversed chirps and confirmed that the A-chirp was most effective chirp configuration. These data suggest that the A-chirp may be optimally suited as a single screening broad-frequency stimulus for rapid ABR threshold estimations in the rodent and could serve to complement more detailed frequency-specific physiologic and behavioral estimates of hearing threshold.

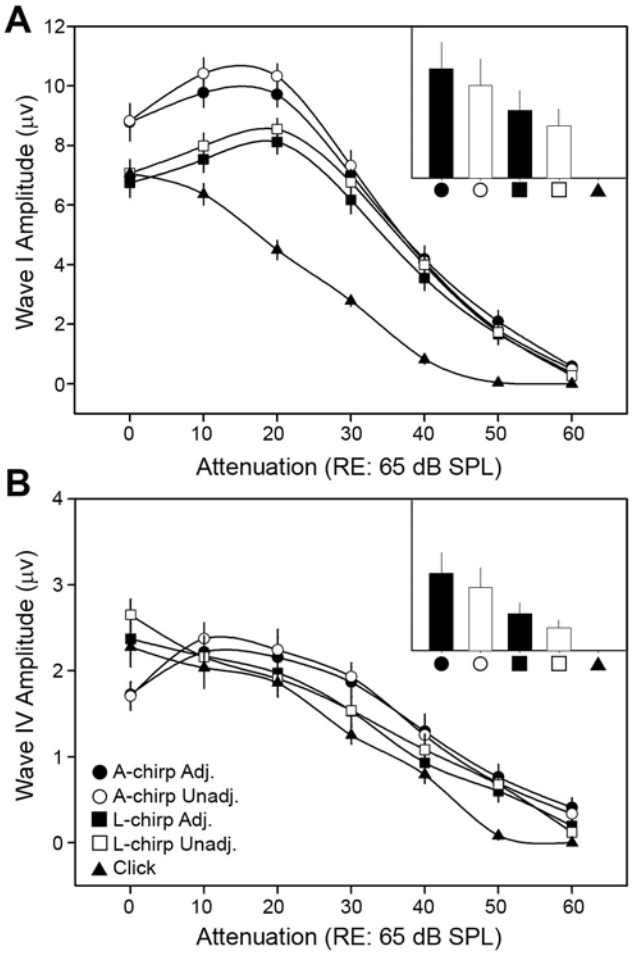

Figure E-9. Amplitude-Level function comparisons for chirp and click stimuli. Comparison of ABR wave I (A) and IV (B) amplitudes for the A-chirp (circles), L-chirp (squares) and click (triangle) for intensities ranging from 0 to 65 dB peak SPL. Responses for each sound level are provided for chirp stimuli adjusted (filled symbols) or unadjusted (open symbols) for the basilar membrane group delay documented at each sound level. Insets: ABR amplitudes documented at 5 dB peak SPL. Symbols correspond to those provided in legend. Ordinate scale = 0–0.8 lv for both graphs. Spankovich *et al.* (2008).

Tan, A.Y.Y, Atencio C.A, **Polley D.B**., Merzenich M.M., and Schreiner C.E. (2007). Unbalanced synaptic inhibition can create intensity-tuned auditory cortex neurons. *Neuroscience* 146(1), 449-462.

Intensity-tuned auditory cortex neurons have spike rates that are nonmonotonic functions of sound intensity: their spike rate initially increases and peaks as sound intensity is increased, then decreases as sound intensity is further increased. They are either "unbalanced," receiving disproportionally large synaptic inhibition at high sound intensities; or "balanced," receiving intensity-tuned synaptic excitation and identically tuned synaptic inhibition which neither creates enhances nor creates intensity-tuning. It has remained unknown if the synaptic inhibition received by unbalanced neurons enhances intensity-tuning already present in the synaptic excitation, or if it creates intensity-tuning that is not present in the synaptic excitation. Here we show, using in vivo whole cell recordings in pentobarbital-anesthetized rats, that in some unbalanced intensity-tuned auditory cortex neurons synaptic inhibition enhances the

intensity-tuning; while in others it actually creates the intensity-tuning. The lack of balance between synaptic excitation and inhibition was not always apparent in their peak amplitudes, but could sometimes be revealed only by considering their relative timing. Since synaptic inhibition is essentially cortical in origin, the unbalanced neurons in which inhibition creates intensity-tuning provide examples of auditory feature-selectivity arising de novo at the auditory cortex. See Figure E-10.

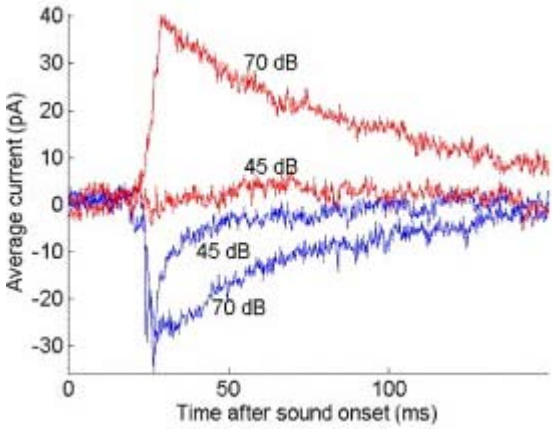

Figure E-10. See text. Tan *et al.* (2007).

Tramontana, M.G., Cowan, R.L., Zald, D., and **Schneider, S.L.** (In preparation) Psychostimulant treatment of TBI-related attention deficits: fMRI analysis of neural mechanisms of response.

The proposed study will apply fMRI methods to examine possible mode(s) of positive action involving stimulant medication in the treatment of traumatic brain injury (TBI)-acquired attention deficits. Although there has been some use of psychostimulant medication in this context, it remains a relatively uncommon clinical practice. The proposed study, by highlighting mechanisms of action, could serve to promote the appropriate application of this type of treatment in this population. It could also set the stage for extending the examination of neural mechanisms of attention deficits and their treatment in other acquired injuries, including brain tumors and strokes. More specifically, the objective is to conduct a small but well-planned study that would provide an empirical basis for hypothesis refinement in a larger and more definitive study on this topic. Also, to our knowledge, this study would represent the first controlled study of stimulant treatment of TBI-acquired attention deficits using a medication option other than methylphenidate.

Wallace, M.T., Carriere, B.N., Morrison, S.P., Derderian, G.A., Royal, D.W. (November, 2007). Spatiotemporal receptive field properties of cortical multisensory neurons," Society for Neuroscience, 37th Annual Meeting, San Diego.

The anterior ectosylvian sulcus (AES) of the cat is comprised on three different sensory representations - the anterior ectosylvian visual area (AEV), the auditory Field AES (FAES) and the fourth somatosensory cortex (SIV). In addition, a large population of multisensory neurons is found at the borders between these unisensory zones, with their modality profiles reflecting the neighboring cortices. Although a defined behavioral and/or perceptual role has yet to be found for AES, its organization and the response properties of its constituent neurons suggest that it may play a role in the transformation of information between the coordinate frameworks for vision, hearing and touch. In keeping with this view, the receptive fields of multisensory AES neurons typically exhibit a high degree of spatial register, despite the fact that

no global spatiotopy has been found for its visual or auditory representations. Such receptive field register has been shown to be an important determinant in the multisensory interactions seen in these neurons. However, preliminary data from AES neurons reveal a striking degree of heterogeneity to the architecture of these receptive fields, an organization that could have important implications for the multisensory interactive product. To examine this issue in more detail, we conducted single unit extracellular recordings from AES neurons in anesthetized and paralyzed adult cats while presenting unisensory and multisensory stimuli at various locations within and outside of the receptive fields. Using this paradigm, the spatiotemporal receptive fields (STRFs) of AES multisensory neurons were found to be exceedingly complex, often exhibiting multiple "hot spots" and widely differing temporal response dynamics. Although the individual unisensory STRFs of these neurons typically showed an overlap of their borders, these STRFs often had a good deal of spatial heterogeneity. Most importantly, in the majority of neurons, the multisensory STRF could not be predicted based on a simple summation of the unisensory STRFs. Rather, this analysis revealed complex combinatorial responses of greater magnitude, shorter latency and longer duration at selected points. Use of this analysis has revealed a striking interplay between space, time and effectiveness in shaping the multisensory responses of AES neurons - interactions that are likely to subserve (and reveal) the still uncharacterized multisensory role of the AES.

Whitton, J., and **Wallace, M.** (March, 2009). Generalization of low-level multisensory perceptual training to a speech task. Poster presented at the Annual Meeting of the America Auditory Society, Scottsdale, AZ.

The ability of the brain to integrate auditory and visual stimuli is dependent on the temporal relationship of those stimuli to one another. Specifically, there exists a temporal window within which auditory and visual stimuli are bound together and processed as a unitary event. Rather than being statically defined, this temporal window has been shown to be malleable. Hence, it can be shifted or even narrowed through perceptual training. Furthermore, it has been shown that this plasticity can generalize to other low-level, multisensory tasks. In the current study, we sought to examine whether these training effects could extend to higher-order multisensory functions such as speech processing. 14 young adults participated in this study. Training participants were asked to complete a battery of three different tasks over a five day period with a one week and one month follow-up. Specifically these tasks were a Simultaneity Judgment Assessment task, a Simultaneity Judgment Training task, and a McGurk Assessment task. Following five days of low-level perceptual training, participants demonstrated significant reductions in their multisensory temporal binding windows. In addition, these participants also showed significant changes in their perceptions of a multisensory speech illusion. Furthermore, these effects remained stable one month following training. [Supported by NIH/NIDCD T35-DC008763]

Williams, C.., and **Hood, L.J.** (March, 2009). Frequency-specific threshold estimation in NICU infants using an ASSR paradigm. Poster presented at the Annual Meeting of the America Auditory Society, Scottsdale, AZ.

The advent of universal newborn hearing screening programs has resulted in a reduction in the age of identification of hearing loss in children. This achievement underscores the need for time-efficient methods in estimating frequency-specific thresholds in infants and young children. This project investigated the use of an intensity-ramped stimulus in an auditory steady-state response (ASSR) paradigm to estimate frequency-specific thresholds in infants hospitalized in the neonatal intensive care unit (NICU) at Vanderbilt University Hospital. Thirteen full term and eleven preterm infants underwent testing before hospital discharge. Testing consisted of: 1) baseline screening auditory brainstem response with 35 dB nHL clicks, 2) intensity-ramped ASSR with tonebursts, and 3) discrete-intensity ASSR. The

results of this study showed that it is possible to estimate frequency-specific thresholds in a time-efficient manner for both full and preterm infants using the intensity-ramped ASSR paradigm. Comparison of these data with previous studies showed that infant response thresholds tended to be similar to those of older children and higher than those measured for adults. Response amplitudes tended to be larger in fullterm than preterm infants and even larger in older children. Noise levels were higher for infants tested in incubators than cribs. [Supported by NIH/NIDCD T35-DC008763.]

ABSTRACTS OF BOOKS AND BOOK CHAPTERS

Berlin, C.I., Keats, B.J.B., **Hood, L.J.**, Gregory, P., and Rance, G. (2007). Auditory Neuropathy/Dys-synchrony (AN/AD). Chapter 4 in Schwartz S. (Ed). *Choices in deafness: A parents' guide to communication options, Third Edition.* Bethesda MD: Woodbine House.

Children with auditory neuropathy/dys-synchrony (AN/AD) are often able to pick up sound waves, but the signals are distorted before they reach their brains. We usually think of sound as having two dimensions: frequency (pitch), and intensity (loudness). But there's actually a third dimension to sound: timing. When you hear sound, and especially speech, you don't just detect pitch and loudness. You also detect rhythms, patterns, and gaps that can be measured in seconds, or even milliseconds. It's timing that distinguishes meaningful speech (e.g., "The butterfly landed on the flower") from gibberish ("Theb utte rfl ylan ded onth efl ow er"). Almost all the hearing losses described in this book can be described by the first two dimensions: frequency (Hz) and decibels (dB). The exception is auditory neuropathy/dys-synchrony (AN/AD). Auditory neuropathy/dys-synchrony is a disorder of timing, so that even faint sounds or tones can sometimes be detected, but the timing of speech is seriously disrupted, especially if there's background noise.

Berlin, C.I., and **Hood, L.J.** (In press). Current physiologic bases of audiologic interpretation and management. In J. Katz, R. Burkard, **L.J. Hood**, and L. Medwetsky (Eds.) *Handbook of clinical audiology, Sixth Edition.*

This chapter reviews current advances in physiology to show how using the pure-tone audiogram alone to gauge hearing may have serious limitations in the presence of auditory neuropathy/dys-synchrony (AN/AD) and similar temporal auditory disorders (e.g., Starr et al., 1996). This chapter stresses the importance of a test battery screen on intake (Jerger and Hayes 1976; Hannley et al. 1983) which includes tympanometry, middle-ear muscle reflexes (MEMR) and otoacoustic emissions (OAE), completed before any behavioral audiometry. The advantages are many beyond correctly identifying AN/AD. Topics discussed include cochlear physiologic responses, identification and characteristics of cochlear microphonics, neural responses from the brainstem including MEMR and auditory brainstem responses, and discussions of how these measures improve accuracy in characterizing various types of hearing losses. Several case studies are presented to illustrate use of physiologic methods with various types of hearing losses. We strongly urge our colleagues to adopt a triage of tympanometry, MEMRs and OAEs on every new patient before pure-tone audiometry is performed. This approach will also allow a valid cross-check with the audiogram to tell audiologists when the results can be trusted and/or used for habilitation.

Conture, E. , and Curlee, R. (Eds.). (2007). *Stuttering and other fluency disorders* (3rd Ed.). Philadelphia, PA: Thieme Medical.

The purpose of this edited book was to update new clinical, research and theoretical approaches and information regarding a host of issues (e.g., bilingualism, neurogenic, pharmacology) impigning on stuttering in children, teens and adults. A wide-variety of nationally and internationally known clinicians and researchers contributed to this volume. The take away message is that progress, substantial progress, has been made, on clinical and research fronts, since the previous volume of this book, progress that has improved the assessment and treatment of stuttering as well as our understanding of the fundamental

nature of stuttering. In conclusion, such advances were taken to suggest that the future is brighter for those who stutter and their families in terms of their academic, emotional, social and vocational possibilities. Preparation of this book was supported in part by NIH/NIDCD research grants 5R01DC000523-14, 1R01DC006477-01A2.

Conture, E., and Walden, T. (Submitted). *Dual diathesis-stressor model of stuttering*.

The purpose of this paper is to discuss a dual diathesis-stressor (DD-S) perspective on developmental stuttering. The chapter initially provides basic considerations regarding childhood stuttering, emotions, speech-language as well as their interactions during social and communicative situations. Following that is a brief, selective review of relevant theory especially those that in whole or in part consider emotional contributions to stuttering. Included among these theories are the repressed need hypothesis (e.g., Glauber, 1958), anticipatory struggle hypotheses (for further review, see Bloodstein and Bernstein Ratner, 2008), diagnosogenic theory (e.g., Johnson, 1963), and two-factor theory of stuttering (Brutten & Shoemaker, 1967). Review of the empirical literature in this area suggests that it typically focuses on (1) adults more than children, (2) negative rather than positive emotionality, (3) emotional reactivity more than emotional regulation and (4) conscious rather than unconscious emotional responses.

Given the above, we suggest that contemporaneous interactions among cognitive, emotional, linguistic and motoric processes most likely contribute to stuttering. Focusing on two such contributors – emotions and speech-language – the authors eschew one-size-fits-all accounts of stuttering. Rather, we attempt to show how these two contributors can concurrently impact children's speech (dis)fluency. These contributors, it is suggested, are best understood through converging lines of evidence, specifically behavioral, cortical, physiological and observational measures (see Campbell & Fisk, 1959 for further discussion of convergent lines of evidence). However, these domains need not be significantly correlated to provide useful information about processes that contribute to stuttering.

Central to this discussion is the notion that "emotion" is a dynamically-changing process rather than a fixed entity. Or, as Cole, Martin and Dennis's (2004) definition suggest, "Emotion is a process, a constant, vigilant process…which periodically reaches a level of detection for the person (i.e., a feeling) or an observer" (p. 319). Likewise, this chapter's consideration of speech-language contributors does not assume that such contributors are delayed or disordered for all children who stutter. Instead we assume – given supportive empirical evidence (e.g., Boey, 2008) – that speech-language is delayed for some, typical for some and for others advanced. This perspective, we believe, provides a better account of speech-language abilities and development of all children who stutter.

From that perspective, the authors' DD-S perspective is presented (see Figure F-1). In essence, this perspective posits two underlying vulnerabilities or diatheses (i.e., emotion and speech-language), each with its own domain-specific stressor. The emotional diathesis (e.g.., lower thresholds for novelty, change and/or difference) is intermittently, but predictably, activated by environmental change. Likewise, a speech-language diathesis (i.e., difficulties quickly, efficiently and spontaneously planning and producing speech-language) is intermittently activated, again predictably so, by environmental requirements for spontaneous, on-the-fly generation of speech. These two diatheses, vulnerabilities, proclivities or tendencies are likely to be genetically endowed but also likely to represent "open" genetic variables, allowing for considerable environmental interaction and influence. Furthermore, the model assumes that variations in stuttering relate to variations in stressors that activate underlying diatheses, but that the stressors need not be unusual or pathological in nature.

The authors conclude with the suggestion that emotional and/or speech-language processes, at least for some children who stutter, play a significant role in the onset, development and maintenance of childhood stuttering. The author's DD-S perspective does not specifically preclude other diatheses, for example, peripheral speech motor control challenges, but it does rest on the notion that the cause of stuttering is neither static nor invariant, accounting for variability in stuttering itself. Although emotional factors may complicate modern-day accounts of developmental stuttering, bringing such factors under the

tent of legitimate contributors to stuttering allows theory to better trace the contours of reality of stuttering. And, by so doing, the field's view of stuttering, rather than being narrowed, will be broadened, made more encompassing and inclusive of multiple possible contributors to this challenging communication disorder. Paper preparation supported in part by NIH/NIDCD research grants R01DC000523-14, R01 DC00647-01A2 and a Vanderbilt University Discovery Grant.

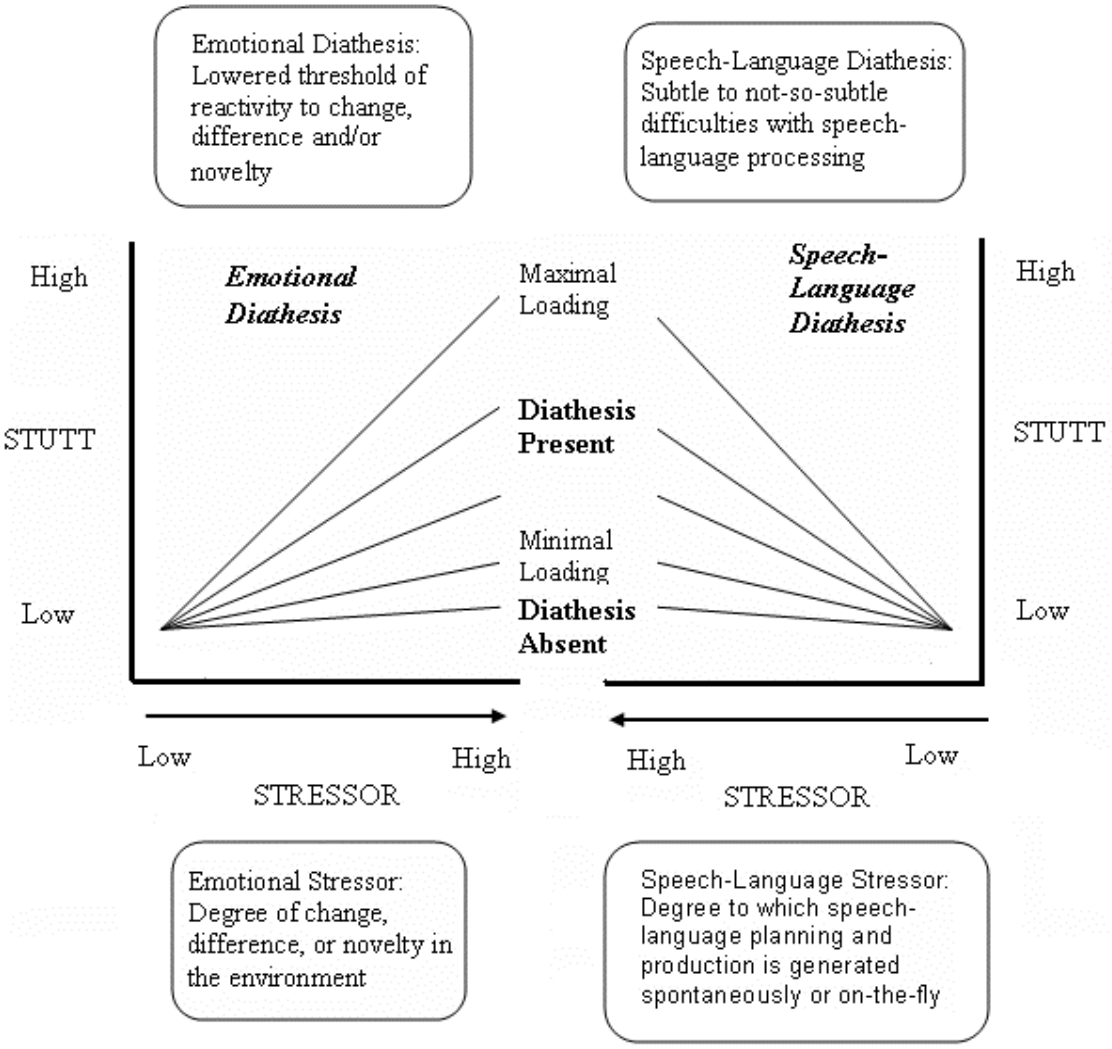

Figure F-1. Dual diathesis-stressor model of stuttering. A speech-language diathesis (i.e., subtle to not-so-subtle difficulties with speech-language processing) and emotional diathesis (i.e., lowered threshold of reactivity to change, difference and/or novelty) are posited, with each vulnerability or predisposition activated by respective stressors. Conture & Walden.

de Riesthal, M. (In press). Central pontine myelinolysis. In *The encyclopedia of oropharyngeal dysphagia in rare conditions*. H.N. Jones and J.C. Rosenbek, Eds., Plural Publishing, Inc.: San Diego.

This book chapter provides a description of the mechanism and pathophysiology associated with Central Pontine Myelinolysis, and the potential effect of this disease on speech and swallowing function.

de Riesthal, M. (In press). Primary progressive aphasia. In *Communication disorders: A case-based approach*. S. Chabon and E. Cohn, Eds., Allyn & Bacon.

This book chapter describes a case of primary progressive aphasia with onset of dementia later in the disease. The evaluation and treatment methods utilized in this case are described and activities and study questions for students are provided.

Golper, L. (2008). Teams and partnerships in aphasia intervention. In R. Chapey (Ed), *Language intervention strategies in adult aphasia, 5th Edition*. Baltimore, MD: Lippincott Williams and Wilkins.

This chapter focuses on interdisciplinary and multidisciplinary teams and partnerships with families in the management of aphasia. A review of the make up of teams and various models for team management is provided and potential causes and ways to avoid interpersonal and interprofessional conflicts within teams. The chapter looks at the progression of priority concerns for aphasic persons and their family during recovery and how to support patients and families throughout that continuum.

Golper, L. (2009) *Medical speech-language pathology: A desk reference*. Clifton Park, NY: Cengage.

This text is a comprehensively revised 3rd edition of the Sourcebook for Medical Speech Pathology. The first two editions were published by Singular Publications (1992, 1998). This text provides a desk reference about medical practices for practicing clinicians and clinicians in training within medical speech-language pathology settings. The text contains fourteen chapters: Speech-Language Pathology in Medical Settings; Communicating Information and Record-Keeping; Vital Signs and the Physical Examination; Mental Status and the Neurological Examination; Nutrition, Hydration, and Swallowing; Medical Genetics; Imaging Studies and Radiologic Oncology; Infectious Diseases and Infection Controls; Cardiac, Pulmonary, Hematologic Functions; Neurologic and Psychiatric Disorders; Acute and Critical Illness; Oncology; Surgeries and Other Procedures; and Rehabilitation Medicine and Geriatrics.

Golper, L. and Brown, K. (2007). Applying research evidence to clinical practice. In R. Lubinski, **L. Golper**, and C. Frattali, C. (Eds.) *Professional issues in speech-language pathology and audiology, 3rd Edition*, Clifton, NY: Delmar-Thomson Publishers, Inc.

Golper and Brown provide a brief history and a tutorial on evidence based practice metrics to clinical decision making in screening, diagnostic assessment, and management decisions.

Gravel, J.S., Seewald, R.C., and **Tharpe, A.M.** (Eds) (In preparation). C*omprehensive handbook of pediatric audiology*. Plural Publishing, Inc.

The Comprehensive Handbook of Pediatric Audiology will be the most wide-ranging and complete work of its kind in the specialty area of pediatric audiology. It will cover knowledge areas and the literature requisite for the provision of the full range of quality, comprehensive pediatric audiologic services to children from the neonatal period through school-age. The Comprehensive Handbook of Pediatric Audiology is envisioned to become the definitive reference in pediatric audiology containing contributions from internationally recognized experts in the field. This text is intended for use in doctoral-level education programs in audiology or hearing science, as well as to serve as an in-depth reference source for practicing audiologists and other professionals, educators, scientists, and policy makers seeking current and definitive information on evidence-based pediatric audiology practice.

Hackett, T. A. (2007). Organization of the thalamocortical auditory pathways in primates. In R. F. Burkard, M. Don & J. J. Eggermont (Eds.). *Auditory evoked potentials: Basic principles and clinical application* (pp. 428-440). Baltimore: Lippincott Williams & Wilkins.

The auditory thalamocortical system is a complex network of ascending, descending, and recurrent connections among neurons in auditory and auditory-related portions of the thalamus and cerebral cortex (Figure F-2). The organization of this system enables neurons in auditory cortex to modulate their inputs in ways that optimize perception. In this chapter, the anatomical and physiological features of the auditory thalamocortical network are reviewed to provide a foundation for other chapters in this volume that describe auditory evoked potential (AEP) generation in this system. Throughout this chapter, the organization of the auditory system in nonhuman primates is used as a model, making relevant extensions to humans wherever possible. Due to the incomplete nature of the primate literature, however, data will also be drawn from other mammalian models for which the datasets are more complete.

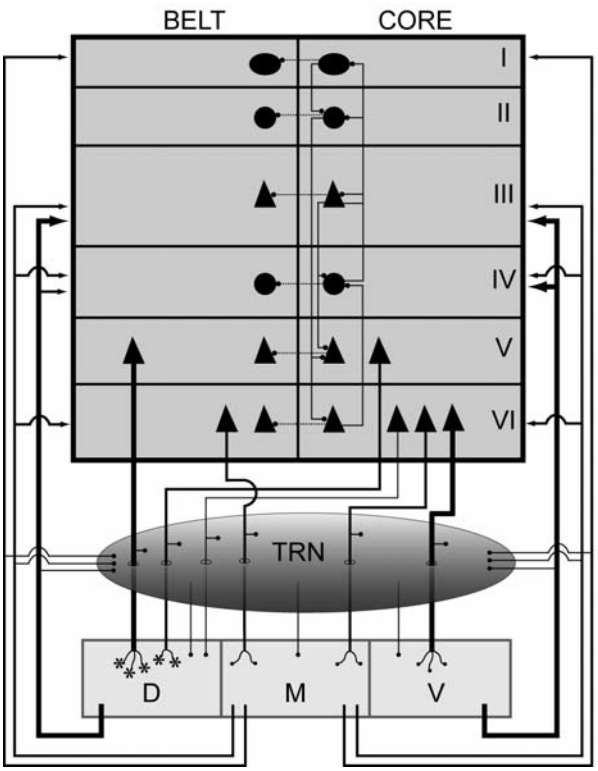

Figure F-2. Thalamocortical (TC), corticothalamic (CT), and corticocortical projections of the auditory cortex and medial geniculate complex (MGC). Layers of cortex indicated by I – VI. Filled symbols (triangles, circles, ovoids) indicate pyramidal and non-pyramidal cells in cortex. Line thickness denotes relative strength of each projection. Ascending TC projections (arrows) from the dorsal (D), medial (M), and ventral (V) divisions of the MGC mainly target layers III and IV of the core (primary) and belt/parabelt (non-primary) areas of auditory cortex, and also send collateral inputs to the thalamic reticular nucleus (TRN). Descending CT projections from neurons in layers V and VI target the MGC and send collateral inputs to the TRN, which projects topographically to each division of the MGC. TC and CT projections of the posterior nuclei are not illustrated. Intrinsic cortiocortical connections link neurons in layers I - VI and neurons in core and belt regions. Filled circles, small CT terminals; asterisks, giant CT terminals. Hackett (2007).

Hackett, T. A. (2007). Organization and correspondence of the auditory cortex of humans and nonhuman primates. In J. Kaas (Ed.), *Evolution of the nervous system* (pp. 109-119.). Oxford: Elsevier.

The identification of areas that contribute to auditory processing in the human cerebral cortex has been the subject of sporadic investigation for more than one century. Although several models of the human auditory cortex have been advanced, none have been widely accepted, and classical descriptions remain influential. In the last fifty years, studies of nonhuman primates and other mammalian species have been emphasized. From these studies, common features of organization have begun to emerge. Of particular interest are comparative anatomical studies of monkeys, apes, and humans in which corresponding regions of auditory cortex have been identified. To some extent, these findings have been validated by functional imaging experiments. While it is not expected that the organization of auditory cortex will be identical across taxa, it appears that homologous areas have been retained, with the possibility that additional areas characterize the auditory cortex of apes and humans. The differences in auditory cortex organization are expected to contribute to well known differences in the perception and production of speech and music among primates, and may also reveal clues about the evolution of these abilities.

Hackett, T. A. (In press). Structure and function of the forebrain auditory callosal system. In J. A. Winer & C. E. Schreiner (Eds.), *The auditory cortex*. New York: Springer-Verlag.

This chapter describes evidence on the anatomy and the function of the forebrain auditory callosal neural system. We begin with a description of callosal organization at a strictly anatomical level, drawing on evidence across species, and sometimes across cortical regions, to provide an impression of the structure of the auditory commissural system in its own right, and of its similarities to commissural systems serving other cortical regions (Figure F-3). We include a brief section on the experience-dependent development of this connectivity. In the second half of the chapter, we explore evidence on the functional correlates of this anatomical organization. We pay particular attention to the empirical link between callosal and intrahemispheric connectivity on the one hand, and binaural auditory processing on the other, and to the hypothesis that callosal connectivity serves to support a continuity of sensation across the midline.

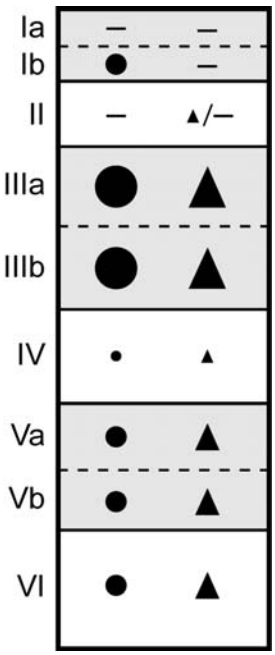

Figure F-3. Relative density of callosal connections of primary auditory cortex by layer. Circles, density of axonal terminals (anterograde); Triangles, cell soma (retrograde); Dashes, no connections. Larger symbols denote greater connection magnitude. The strongest callosal connections arise from and terminate in layer III. Connections with other laminae are generally weakest in layers II and IV. Hackett.

Hale, S.T., and **Evans, L.H.** (In press). Case study of a school-aged articulation disorder. In E. Cohn & S. Chabon (Eds.), *Communication disorders: a case based approach*. Boston: Allyn & Bacon.

One of forty case studies presented in this compendium which includes studies across the scope of practice and life span, this chapter focuses on a school-aged child. The theoretical underpinnings and evidence-based approaches to remediation are described in the context of the evaluation and management of the child who exhibits both articulation errors and a phonological disorder.

Hood, L.J., and Keats, B.J.B. (In preparation). Genetics of childhood deafness. In Gravel, J.S., and Seewald, R.C. (Eds.) *Comprehensive handbook of pediatric audiology*. San Diego: Plural Publishing.

This chapter addresses phenotypic and genotypic characteristics of inherited hearing loss in pediatric populations. Topics covered include epidemiologic and demographic aspects of genetic hearing loss, patterns of inheritance, syndromic and non-syndromic hearing loss, genetics of auditory neuropathy/dys-synchrony, audiologic characteristics, newborn hearing screening, ethical issues, and partnerships of audiologists with geneticists and genetics counselors.

Jacobson, G.P., and **McCaslin, D.L.** (2007). The vestibular evoked myogenic potential and other sonomotor evoked potentials. In: Burkard, R. Eggermont, J, Don M. (Eds) *Auditory evoked potentials: Basic principles and clinical application*. Lippincott Williams and Wilkins. 572-598.

In the late 1950's, researchers were interested in using signal averaging to record neurogenic responses from the human scalp. Among these investigators were Geisler and colleagues who recorded what they regarded as evoked brain activity in response to unfiltered click stimuli. However, Bickford and associates and Cody and associates demonstrated that these responses were attenuated in the presence of medications designed to produce muscle relaxation and paralysis. Ruhm and colleagues demonstrated in direct brain recordings of a patient undergoing a neurosurgical procedure that only a small portion of the electrical activity recorded from the human scalp in the 10- to 30 msec period actually was generated by the brain. These evoked potentials, initially referred to as fast responses, became known in contemporary terms as middle-latency responses. The balance of the electrical activity represented sound-evoked muscle reflexes, or sonomotor responses.

Jacobson, G.P., and Shepard, N. (Eds.) (2008). Balance function assessment and management. Plural Publishing, San Diego.

Jacobson, G.P., and **McCaslin, D.L.** (2008). Assessment of falls risk in the elderly. In: **Jacobson, G.P.** and Shepard, N. (Eds) *Balance function assessment and management*. Plural Publishing, San Diego, 585-612.

Unintentional injury, which almost always results from a fall, ranks as the 6th leading cause of death in the elderly population. Since audiologists are referred for vestibular assessments patients who are "dizzy" we have a unique opportunity to communicate back to the referral source that the patient's disequilibrium may require a more in-depth and multifactorial assessment. In much the same way that we "identify" and then "intervene" for hearing impairments, audiologists have the opportunity to assume a leadership role in the identification of elderly who are at greatest risk for falling and to suggest the referral sources other professionals who might intervene to reduce the risk and help independent elderly remain independent.

The current chapter should serve as a guide for those clinicians who are interested in developing a falls risk assessment clinic.

Jacobson, G.P., and Newman C.W. (2008). Assessing dizziness-related quality of life. In: **Jacobson, G.P.** and Shepard, N. (Eds) *Balance function assessment and management*. Plural Publishing, San Diego. 99-131.

The assessment of the vertiginous, "dizzy" and unsteady patient has evolved from a quantification of impairment, to an assessment of impact of that impairment on psychosocial function. The addition of this information is valuable because there is generally a weak predictive relationship between the two forms of measurement. Thus, self-report measures provide unique data that becomes important, for example, in the assessment of severity of a disease and in the quantification of improvement following treatment. This chapter is aimed to: 1) introduce the reader to contemporary concepts in classification of impairment, disability, and handicap (i.e. dizziness-related activity limitation and participation restriction), 2. describe commonly used devices for assessing these spheres, and, 3. illustrate how one has been used as a dependent variable in clinic-based research.

Jacobson, G.P., Shepard N.T.**, Dundas J.A., McCaslin, D.L.,** and **Piker, E.G.** (2008). Eye movement recording techniques. In: **Jacobson, G.P.**and Shepard, N. (Eds) *Balance function assessment and management*. Plural Publishing, San Diego, 27-44.

The information in this chapter provides for a basic foundation in the various eye movement recording techniques used in both assessment of eye movement abnormalities and the dizzy patient. While these methods allow for archival information one must not overlook the method of direct visualization. The well-trained and experienced examiner can obtain a thorough and accurate assessment of the dizzy patient with the use of little in the way of equipment. As is the case in all aspects of the evaluation of the patient with complaints of dizziness and balance disorders, the patient's presenting signs and symptoms via the intake history, constitute the paramount information for the diagnosis and decisions on management. Therefore, the recorded movements of the eyes, no matter how abnormal, need always to be interpreted in the context of the patient's neurotologic history.

Jacobson, G.P., McCaslin, D.L., Grantham, S.L., and Shepard, N.T. (2008). Within and between measure relationships between balance function tests. Illustrative cases. In: **Jacobson, G.P.**and Shepard, N. (Eds) *Balance function assessment and management*. Plural Publishing, San Diego, 613-635.

In this chapter we will provide the reader with data showing how the results of the foundation assessments of the balance function tests correlate with one another. That is, in the same way that a Type B tympanogram and absent stapedial reflexes on the probe side predicts a conductive hearing loss, we will see that a 100% unilateral caloric weakness predicts a phase lead and reduced VOR gain at .01 Hz. We then provide the reader with case study examples of how the results of one test, do in fact predict the results of another test.

Justice, L. M., Gillon, G., and **Schuele, C. M.** (2009). Phonological awareness: Description, assessment, and intervention. In J. Bernthal, N. Bankson, & P. Flipson (Eds.), *Articulation and phonological disorders: Speech sound disorders in children* (6th ed., pp. 357-383). Boston: Allyn & Bacon.

This chapter provides an introduction to phonological awareness within the context of a textbook typically used in graduate courses in speech-sound disorders. The content includes definitions of phonological awareness, an overview of development and methods for assessment and intervention.

Key, A. (Submitted). Human auditory processing: Insights from event-related potentials. To appear in **Camarata S., Polley, D., Wallace, M**. (Eds).

Animal studies provided valuable data regarding the general structure and function of the primate auditory cortex. However, the human brain is not identical to that of any animal model, and the human auditory functioning includes aspects not present in other primates (e.g., language). Therefore, studies of human auditory cortex are critically important. Advancements in non-invasive neuroimaging techniques (e.g., functional magnetic resonance imaging, fMRI; electroencephalography, EEG; magnetoencephalography, MEG) provide an opportunity to examine various aspects of human auditory cortex. This chapter provides on overview of the uses of cortical event-related potentials (ERPs) for investigation of human auditory function. First, a brief introduction to the ERPs is provided. The following sections demonstrate the success of using ERPs to address questions previously studied using more invasive methods, such as cortical maturation, functional organization, and plasticity. A separate section examines findings regarding auditory development and functioning following deprivation as well as restoration of auditory input. The final section describes ERP studies examining multisensory interactions in the auditory cortex. From this review it should be clear that the ERPs can be a valuable tool for investigating a wide range of questions concerning human auditory functioning and provide insights into brain-behavior connections.

Leon, S.A., Nadeau, S.E., **de Riesthal, M.**, Crosson, B., Rosenbek, J.C., and Gonzalez Rothi, L.J. (2007). Aphasia. In *Cognitive neurorehabilitation* (2nd Edition). D. Stuss and I. Robertson, Eds., Cambridge University Press: New York.

This book chapter provides a review of treatment outcomes research in aphasia. Specific treatment techniques are discussed in the context of levels of evidence and the place of the current literature in the five phase model of treatment outcomes research.

Lubinski, R. **Golper, L.** and Frattali, C. (Eds.) (2007). Professional issues in speech-language pathology and audiology, 3rd Edition, Clifton, NY: Delmar-Thomson Publishers, Inc.

This 3rd edition provides an updated and broad-scoped coverage of professional issues in speech-language pathology and audiology, with chapter contributions from known experts in the profession. Chapters cover the history of the professions; scope of practice in audiology and speech-language pathology; credentialing; professional organizations; ethics; professional liability; international alliances; workforce issues; professional autonomy and collaboration; support personnel; special populations; health care legislation, regulations, and financing; common acronyms and abbreviations; policies affecting education settings; service delivery in the schools; service delivery in early intervention; promoting access to audiology and speech-language pathology services; providing quality care; leadership and communication; infection prevention; child and elder abuse; service delivery with culturally and

linguistically diverse populations; supervision and the supervisory process; technology; stress and conflict management in the work place; evidence based practices; and the future of our science.

Lubinski, R. and **Golper, L.** (2007) Professional Issues: from Roots to Reality. In R. Lubinski, **L. Golper,** and C. Frattali, C. **(**Eds.) (2007). *Professional issues in speech-language pathology and audiology, 3rd Edition,* Clifton, NY: Delmar-Thomson Publishers, Inc.

In this chapter, Lubinski and Golper trace the roots of the discipline of communication sciences and disorders from antiquity through the present and examine how that history is reflected in present day practices and issues.

McCaslin, D.L., Dundas, A., and **Jacobson, G.P.** (2008). The bedside assessment of the vestibular system. In: **Jacobson, G.P.** and Shepard, N. (Eds) *Balance function assessment and management*. Plural Publishing, San Diego, 63-97.

The results of informal tests of vestibular function such as those described in this chapter are commonly considered to be well-established criteria for the appropriate referral of patients for diagnostic testing. However, a review of published literature regarding the tests in question does not support such a conclusion. Rather, these tests may be most appropriately used to alert the examiner that special care should be taken during a particular subtest when laboratory testing is being performed, or that additional testing is warranted. Although the tests reviewed in this chapter tend to exhibit high specificity, their attendant low sensitivity renders them relatively unsuitable for clinical use. As such, informal assessment tools should not be considered to be substitutes for electrophysiologic testing. If bedside tests are to be included in the screening and referral process , new or improved versions and combinations of the tests must be developed, investigated, and proven by clinical scientists. Without such developments, it is likely that reliance on bedside tests of vestibular function may lead to missed diagnoses or inappropriate referrals for testing and follow-up care.

McCrae, E., and **Golper, L.** (2007). Supervision. In R. Lubinski, **Golper, L.** and C. Frattali (Eds.). *Professional issues in speech-language pathology and audiology, 3rd Edition*, Clifton, NY: Delmar-Thomson Publishers, Inc.

In this review of the supervision, McCrae and Golper review both the developmental supervision processes in clinical training programs and supervision in the workplace. The chapter emphasizes the importance of feedback and mentorship throughout clinical development.

Richels, C., and **Conture, E.** (2007). Early intervention for stuttering: An indirect method. In **E. Conture** and R. Curlee, R. (Eds.). *Stuttering and other fluency disorders* (3rd ed., pp. 77-99). Philadelphia, PA: Thieme Medical.

The purpose of this chapter is to discuss a family-centered, indirect treatment approach for preschool-age children who stutter (CWS). After an initial discussion of literature pertaining to the treatment of preschool-age CWS, the chapter presents rationale, strategies, tactics and outcome data regarding this treatment approach, which is in its 25th year of practice, first at Syracuse and now at Vanderbilt University. The chapter concludes with a summary of the essential aspects of the program as well as areas in need of future research and modification. It is hoped that readers of this chapter will better understand the importance of including families in the treatment of young CWS, routine collection of

behavioral data, and reporting such data to the child's caregivers. Additionally, we believe, clinicians should then be able to appropriately modify the approach we describe to best fit various service delivery settings. Preparation of this chapter supported in part by NIH/NIDCD research grants 5R01DC000523-14 and 1R01DC006477-01A2.

Richels, C., and **Conture, E.** (2008). Indirect treatment of childhood stuttering: Diagnostic predictors of treatment outcome. In Guitar, B. & McCauley, R. (Eds). *Treatment of stuttering: Emerging and established approaches*. Baltimore, MD: Lippincott, Williams & Wilkins.

The purpose of this chapter is to discuss the role of assessment as a means of diagnosing childhood stuttering as well as informing clinicians about the course and outcome of treatment. The chapter focuses on the assessment of preschool (ages 2.5- to 5-year-olds) and young school-age (ages 5- to 6-years 11-months-old) children who stutter (hereafter referred to as child or children). This age-range was selected because it brackets the time period during which the onset of stuttering is most likely to occur (e.g., Maansson, 2007; Yairi & Ambrose, 2005; Yaruss, 1999; Yaruss, LaSalle & Conture, 1998) and when the differential diagnosis of children with incipient stuttering versus transient disfluency is most challenging (Curlee, 1993, Finn, Ingham, Ambrose, & Yairi, 1997). The authors begin by discussing the theoretical underpinnings that guide their assessment procedures as well as the empirical support for our means of assessing children known or thought to be stuttering.

Following this discussion, the chapter presents the rationale, strategies, and outcome data regarding the present authors' approach to assessment as it relates to successfully implementing treatment for children who stutter. The chapter concludes with a summary of what the authors believe to be the essential aspects of assessing children as well as areas in need of future exploration and modification. It is hoped that the reader of this chapter will better understand the importance of the initial assessment of children and families in the treatment of young children who stutter. Additionally, we believe that clinicians should then be able to appropriately modify our approach to best fit various service delivery settings as well as the individual needs of their young clients and their families. Preparation of this chapter supported in part by NIH/NIDCD research grants, 5R01DC000523-14 and 1R01DC0006477-01A2.

Ricketts, T.A., and **Hornsby, B.W.Y.** (2007). Estimation of directional benefit in real rooms: A clinically viable method. In R.C. Seewald (Ed.) *Hearing care for adults 2006: Proceedings of the first international conference*, Phonak, Chicago.

The aided sentence recognition, in noise, for fourteen adult participants with symmetrical sensorineural hearing impairment was measured in four environmental conditions in fixed directional, adaptive directional and omnidirectional modes. A single room, containing four uncorrelated noise sources served as the test environment. The room was modified to exhibit moderate (RT60 = 0.9 seconds) levels of reverberation. Sentence recognition was measured at two different speech loudspeaker-to-listener distances (1.2 m, and 4.8 m). STI measures were also made in each of the listening conditions. Results revealed a decrease in directional benefit with increasing distance. Although reduced, directional benefit was still present at the farthest speech speaker-to-listener distance tested in this experiment. The pattern of average sentence recognition results across varying distances and two different reverberation times agreed with the pattern of STI values measured under the same conditions. Further, as shown in the Figure F-4, the pattern of results was also predictable from the relationship observed in a previous experiment (Ricketts and Hornsby, 2003). These data provide further support for the use of aided STI values for the prediction of average word recognition across listening conditions which differ in reverberation, microphone directivity and speaker-to-listener distance.

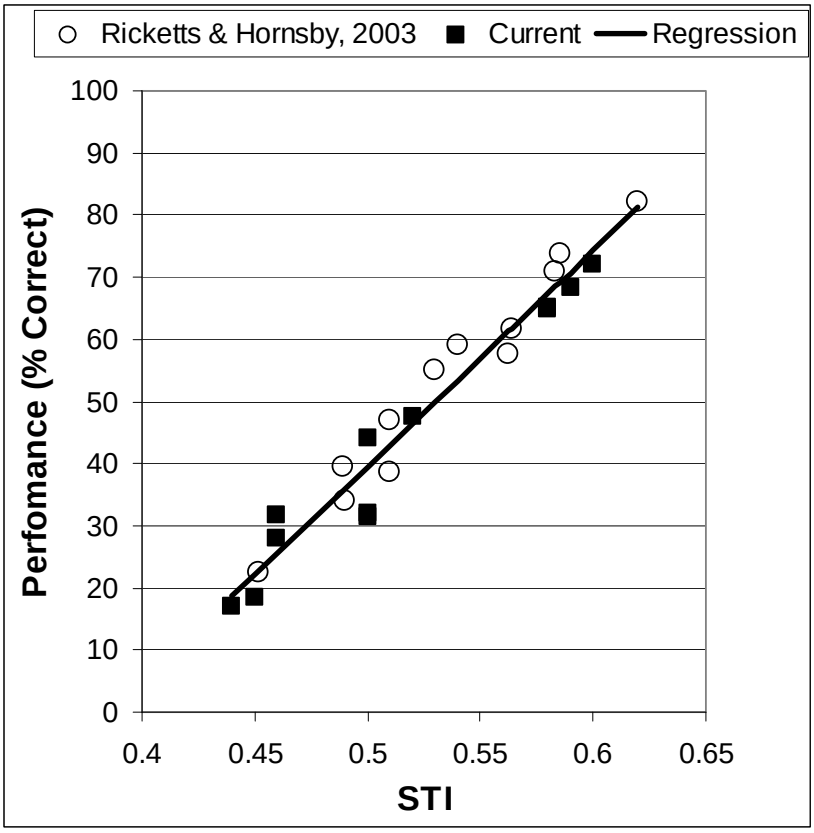

Figure F-4. See text. Ricketts & Hornsby (2007).

Ricketts, T.A., Bentler, R.A. and **Mueller, H.G.** (In preparation). *Hearing aids: Fundamentals*. Plural Publishing.

Schroeder, C. E., Lakatos, P., Smiley, J., and **Hackett, T. A.** (2007). How and why is auditory processing shaped by multisensory convergence? In R. F. Burkard, M. Don & J. J. Eggermont (Eds.), *Auditory evoked potentials: basic principles and clinical application* (pp. 651-670.). Baltimore: Lippincott Williams and Wilkins.

Our subjective world is a basically seamless multisensory experience, even though empirical studies tell us that this perception is computed by our brains by combining inputs from different sensory systems. Studies in both monkeys and humans have revealed multisensory convergence and interaction at and above the auditory belt level of processing. Auditory cortical responses are enhanced or suppressed depending on the phase of ongoing local oscillatory activity during which inputs arrive. Oscillatory phase can be modified by sensory input. Thus, nonauditory inputs may enhance the processing of related sounds by resetting the phase of ambient oscillations so that the related auditory inputs tend to arrive during optimal excitability periods. There is evidence that oscillation and phase reset effects are largest for biologically relevant sounds, such as vocalizations.

Schuele, C. M., Skibbe, L., and Rao, P. (2007). Assessing phonological awareness. In K. Pence (Ed.), *Assessment in emergent literacy* (pp. 275-325). San Diego: Plural Publishing.

This book reviews assessment procedures across the many areas encompassed by emergent literacy. In this chapter, measures of preschool and kindergarten phonological awareness are evaluated. Measures include norm-referenced, screening, progress monitoring, and criterion-referenced assessments.

Tharpe, A.M. (2008). And they do grow up…". In R.C. Seewald and J. Bamford (Eds.). *A sound foundation through early amplification 2007: Proceedings of the fourth international conference*, Great Britain: Cambrian Printers.

In the early stages of working with families of children with hearing loss, much of our focus is appropriately on educating and supporting adult family members about the potential impact of hearing loss on their young child. We provide families with information about hearing loss, hearing technology, and communication and education options. In addition, we provide emotional support to families as they attempt to cope with what is typically viewed as difficult news about their child's hearing. At some point, audiologists transition from family-focused to more child-focused care. There are numerous indications that this re-focusing of our counseling efforts is of critical importance. Children with hearing loss are reported to have more behavioral and emotional problems than those with normal hearing (e.g., Schum 1991; Marshark 1993; Capelli, Daniels, Durieux-Smith, McGrath, and Neuss 1995). These problems can ultimately manifest themselves in adolescence and young adulthood through increased substance abuse, sexual activity, and school drop out rates relative to individuals with normal hearing (e.g., Cairns, Cairns, and Neckerman, 1989; Hawkins and Fitzgibbon 1993; Dodge, Lochman, Harnish, Bates, and Pettit 1997; Stinson and Walter 1997). Barriers posed by hearing loss are implicated as contributors to these problems yet may be penetrable with appropriate assistance through counseling and technology. This chapter elucidates some factors that might be contributing to developmental barriers for children with hearing loss. In addition, the role of audiologists in supporting healthy emotional and behavioral development of families and children with hearing loss across the age range is explored.

Tharpe, A.M. (2009). Individuals with multiple disabilities. In J. Katz, R. Burkard, **L.J. Hood**, and L. Medwetsky (Eds.) *Handbook of clinical audiology, Sixth Edition*.

Individuals with hearing loss and additional disabilities represent a widely diverse and complex population. They differ in the type and degree of their hearing loss, the type and degree of their accompanying disability, and their overall level of functioning. Approximately 30-40% of newborns who are deaf or hard of hearing have additional neurodevelopmental conditions, most often mental retardation (Fortnum & Davis, 1997; Mace, Wallace, Whan, & Stelmachowitz, 1991; Van Naarden, Decoufle, & Caldwell, 1999). Similarly, the Gallaudet Research Institute (2005) indicated that approximately 42% of deaf or hard of hearing school-age children have additional disabilities. As seen in Table 1, the most prevalent conditions were intellectual disabilities, followed by learning disabilities and attention problems. It is also possible that some disabilities may not become apparent until well into childhood or adolescence increasing these numbers even more. The purpose of this chapter was to address the modification of audiologic assessment and management strategies for children with hearing loss who have additional disabilities.

Table 1. Percent of Disabilities that Occur in Children with Hearing Loss

Additional Disabilities	% of Children with Hearing Loss
No additional disabilities	57.6
Low vision – legal blindness	4.6
Intellectual disability	10.0
Autism	1.0
Orthopedic disability (including cerebral palsy)	3.7
Learning disability	9.2
Attention deficit disorder/ Attention deficit hyperactivity disorder	6.3
Emotional disability	1.9
Other	6.9

Tharpe, A.M. (2008). Minimal hearing loss in children: The facts and the fiction. In R.C. Seewald and J. Bamford (Eds.) *A sound foundation through early amplification 2007: Proceedings of the Fourth International Conference*, Great Britain: Cambrian Printers.

Children with minimal degrees of hearing loss have been of interest to audiologists for decades but particularly since the 1980s. Some of the most extensive studies of that time were conducted under the direction of Bess (1986). It was at that time that the impact of minimal hearing loss on child development was realized and policy changes began to be implemented in an attempt to improve outcomes. A starting point in our discussion of this topic should reasonably be the definition of what is meant by minimal hearing loss. However, even the term "minimal" is controversial as it might imply that these losses are not important or are inconsequential. Furthermore, it is common for varying degrees and configurations of hearing loss to fall into the general category of "minimal". In 1998, Bess and colleagues defined minimal hearing loss as

- unilateral sensorineural hearing loss - average air-conduction thresholds (.5, 1.0, 2.0 kHz) $\geq$20 dB HL in the impaired ear and an average air-bone gap no greater than 10 dB at 1.0, 2.0, and 4.0 kHz and average air-conduction thresholds in the normal hearing ear $\leq$15 dB HL;
- bilateral sensorineural hearing loss - average pure-tone thresholds between 20 and 40 dB HL bilaterally with average air-bone gaps no greater than 10 dB at frequencies 1.0, 2.0, and 4.0 kHz;
- high-frequency sensorineural hearing loss - air-conduction thresholds greater than 25 dB HL at two or more frequencies above 2 kHz (i.e., 3.0, 4.0, 6.0, or 8.0 kHz) in one or both ears with air-bone gaps at 3.0 and 4.0 kHz no greater than 10 dB.

Since that time, others have adopted these definitions in an effort to enable meaningful comparisons of data across studies (Centers for Disease Control and Prevention 2005). Our attempts to evaluate current data obtained across studies are compromised when we are not using uniform definitions. For example, prevalence rates of minimal or mild bilateral hearing loss and unilateral hearing loss are uncertain because of the differences in defining the audiometric thresholds of these groups. Furthermore, because we do not currently target minimal and mild degrees of hearing loss with our newborn hearing screening programs, we can only estimate prevalence of such losses in the newborn period. Johnson and colleagues (2005) offered a conservative estimate of .55/1000 newborns with mild permanent bilateral (25-40 dB at 1.0, 2.0, or 4.0 kHz) and unilateral hearing loss. The number of babies with unilateral hearing loss in the neonatal

period has been estimated at .7 – 1/1000 (Prieve et al. 2000; Davis, DeVoe and Robertson 2005) as compared to 3/100 by school age (Bess et al. 1998). Bess and colleagues also estimated 2.4/100 school-age children had minimal bilateral hearing loss. The difference between estimated prevalence rates in the newborn period and at school age can be the result of several different factors including:

- misses by the early hearing detection and intervention systems (EHDI);
- low follow up rates by newborn screening programs resulting in low estimates in the newborn period;
- progressive or late-onset hearing loss; and/or
- differing definitions of "hearing loss".

This chapter reviews what we know about the impact of minimal degrees of hearing loss on children. Perhaps more importantly, what we do not know about the effects of these degrees of hearing loss is also discussed.

Tharpe, A.M., and Sladen, D.S. (2008). Hearing loss, In T.K. McInerny, H.M. Adam, D.E. Campbell, D.K. Kamat, and K.J. Kelleher (Eds.), *American Academy of Pediatrics textbook of pediatric care 1st ed.*, Elk Grove Village, IL: American Academy of Pediatrics.

Throughout the course of their practice lifetime, pediatricians will encounter approximately a dozen children who have severe to profound hearing loss. Pediatricians typically are the first health care practitioners approached by parents when they have concerns about their child's hearing. However, we know that although parents become concerned about their child's hearing rather early (at approximately 6 months of age) when the hearing loss is severe, milder forms of hearing loss typically do not generate concern until children reach school age and these losses are often not identified through newborn hearing screening. As such, it is imperative that pediatricians recognize the signs, symptoms, and risk factors for hearing loss in children and become aware of appropriate referral paths. The purpose of this chapter was to present the signs and symptoms of childhood hearing loss and to instruct pediatricians on appropriate identification and referral options.

SOURCES OF FUNDING

CURRENTLY ACTIVE SUPPORT

Source & number: MCHB MCJ000217-53 -- Fred H. Bess/Edward Conture/Anne Marie Tharpe, Principal Investigators
Title: Center for Communication Disorders in Children
Project period: 7/01/08 - 6/30/13
Description: To train students in speech-language pathology and audiology from Vanderbilt University School of Medicine and Tennessee State University.

Source & number: DOE/H325D050047--Fred H. Bess, Principal Investigator
Title: Preparation of Tomorrow's Leaders in Pediatric Audiology and Early Intervention
Project period: 10/1/05 - 9/30/09
Description: This grant supports graduate level personnel with specialized training on infants and toddlers with hearing loss—especially in the area of early intervention services.

Source & number: DOE/H133G050211--Fred H. Bess, Principal Investigator
Title: Psychoeducational Impact of Minimal Sensorineural Hearing Loss in Children
Project period: 10/1/05 – 9/30/09
Description: The objectives of this study are to identify young school-aged children with minimal sensorineural hearing loss (MSHL) and to assess the relationship of MSHL to psychoeducational development.

Source & number: DOE/H325K070313A — Fred H. Bess, Principal Investigator
Title: Preparation of Audiologists to Serve Infants and Toddlers with Hearing Loss
Project period: 7/1/07-6/30/11
Description: This grant supports graduate level personnel with specialized training on the special needs of infants and toddlers with hearing loss.

Source & number: 1R01DC008640-01 – Stephen Camarata, Principal Investigator
Title: Treatment of Speech Disorders in Children with Down Syndrome
Project period: 9/1/07-8/31/10
Description: This project is designed to develop more effective treatments for speech disorders in children with Down Syndrome.

Source & number: 3R01DC008640-02S1 – Stephen Camarata, Principal Investigator
Title: Treatment of Speech Disorders in Children with Down Syndrome/Research Supplement
Project period: 9/1/08-8/31/10

Description: This project is designed to provide a postdoctoral student with an opportunity to gain research experience as a postdoctoral fellow on an ongoing research project in accordance with stated goals of "broadening research experience" and in accordance with the objectives of the program announcement.

Source & number: R324A080143 – Stephen Camarata, Principal Investigator
Title: TOP9 and G2 Related Services Intervention for Expressive and Receptive Language Skills in ASD and in CI
Project period: 7/1/08-6/30/11
Description: This purpose of the proposed project is to systematically develop, using single subject design, whether an intervention for improving receptive language (as well as expressive language) in preschool children with mild-moderate cognitive impairments and to develop this intervention program for preschool children with ASD.

Source & number: NIH-NEY/2R24EY12894 – Subcontract with Western Michigan University – Daniel H. Ashmead, Principal Investigator
Title: Blind Pedestrians' Access to Complex Intersections
Project period: 7/1/08-6/31/13
Description: The central aims of this program are to use the strengths of a multi-disciplinary team to understand the perceptual and cognitive requirements of negotiating complex intersections without vision and with low vision; to design and test engineering and training solutions to problems of information access that are currently known and that are identified in the course of this partnership and to produce materials about the problems and solutions that are useful to transportation engineers, individuals with visual impairments, and rehabilitation personnel.

Source & number: NIH-NIDCD/1R01DC006477 – Edward G. Conture, Principal Investigator
Title: Emotional Reactivity, Regulation & Childhood Stuttering
Project period: 2/1/06-1/31/10
Description: The specific aims of this study are an initial attempt to relate emotional development and behavior to childhood stuttering when children are confronted with change or challenge.

Source & number: Malcolm Fraser Foundation – Edward G. Conture, Principal Investigator
Title: Parent-Child Stuttering Group
Project period: 7/1/98-8/31/09
Description: To permit the DHSS to refine and expand upon the quality and quantity of our speech-language pathology services for people who stutter and their families in the Middle Tennessee and surrounding regions.

Source & number: NIH-NIDCD/5R01DC04318 – Troy Hackett, Principal Investigator
Title: Functional Organization of the Auditory Cortex
Project period: 5/1/08-4/31/13
Description: The first specific aim is directed at one of the most tentative aspects of the model which suggests that the medial and lateral portions of the belt region are functionally-distinct. As a second aim, we will compare architectonic features of auditory cortex in non-human primates and humans.

Source & number: NIH-NIMH/2R01MH061989 – Subcontract with Nathan S. Kline Institute - Troy Hackett, Principal Investigator
Title: Somato-Auditory Convergence: Supratemporal Plant
Project period: 8/1/05-7/31/10
Description: The specific aim of this project is to define the mechanisms of multisensory interactions in auditory cortex, and their contributions to the auditory functions of the region.

Source & number: Association of University Centers on Disabilities –Anne Marie Tharpe Principal Investigator
Title: Tennessee-Vanderbilt MCH-LEND Pediatric Audiology Training
Project period: 1/15/09-1/14/12
Description: The primary purpose of this project is to expand and enhance our pediatric audiology training within the LEND/MIND program. We plan to focus our efforts on preparation of highly competent professionals at Vanderbilt University and at the other selected LEND programs to meet the underserved needs of infants, young children, and adolescents with hearing loss.

Source & number: Private Foundation, Anne Marie Tharpe, Principal Investigator
Title: Proposal for Master's Degree Program in Education of the Deaf and a Concurrent Specialty Track for Audiology and Speech-Language Pathology Students
Project period: 9/1/05-8/31/10
Description: The specific aims of this program will emphasize the development of spoken language, effective audiologic management, counseling, and family-centered service provision.

Source & number: H325K060403—LeeAnn Golper, Principal Investigator
Title: Clinical Specialty Preparation to Serve Infants, Toddlers, and Children with Feeding and Swallowing Disabilities
Project period: 10/1/07-9/30/010
Description: This project supports the specialty preparation of speech-language pathology graduate students and occupational therapy students to provide highly qualified, evidence-based clinical services to children with dysphagia in association with low incidence disabilities.

Source & number: H325D080075– C. Melanie Schuele, Principal Investigator
Title: Preparation of Teacher/Scholars in Language and Literacy
Project period: 8/1/08-7/31/09
Description: The purpose of this project is to provide specialized training in language and literacy at the doctoral level to Ph.D. student.

Source & number: N/A VA IPA—Todd A. Ricketts, Principal Investigator
Title: Evaluation of Open-Canal and Traditional Custom Fit Hearing Aids
Project period: 10/15/08-10/14/11
Description: The goal of this work is to develop an evidence-based hearing aid selection model based on hearing aid style factors. A total of 13 hearing-aid fitting and style-related factors are measured in a large (n = 288), randomized-controlled, three-site clinical trial, utilizing a three-period (two months each), cross-over design which compares traditional and open canal fittings.

Source & number: H133G060012—Todd A. Ricketts, Principal Investigator
Title: Appropriate Directional Hearing Aid Switching in School Aged Children
Project period: 11/1/06-10/31/09
Description: The purpose of the research is to answer questions through a series of three investigations which include 1) quantification of school environments with regards to the most appropriate microphone mode (directional, omnidirectional, either); 2) quantification of appropriate switching of both automatic and manual directional switching systems in school environments as a function of age; and 3) quantification of speech recognition across a range of school listening environments for asymmetric and traditional symmetric microphone fittings (both automatic and manually switched).

Source & number: Phonak, AG -- Todd A. Ricketts, Principal Investigator
Title: Open Canal Verification and Examination of Listening Effort
Project period: 3/1/08-6/30/09
Description: The proposed research falls under two general umbrellas. The first, includes projects related to appropriate and optimal gain, processing and features for open canal style hearing instruments. The optimal OC prescriptive targets identified in experiment 1 will be further refined in experiment 2. specifically, we will focus on identifying any negative effects of summation and cancellation on sound quality by comparing three prescriptive targets using a simulated OC instrument.

Source & number: Department of Education/H325D080075 – Melanie Schuele Principal Investigator
Title: Preparation of Teacher/Scholars in Language and Literacy
Project period: 7/1/08-6/30/12
Description: The purpose of this project is to provide specialized training in language and literacy at the doctoral level to Ph.D. student.

Source & number: NIH/NIDCD/1R03DC007329, Melanie Schuele, Principal Investigator
Title: Complex Syntax Production of Children with SLI
Project period: 1/15/06-12/31/09
Description: The specific aims of this project are two-fold: a) to establish methodology for investigation of complex syntax production in young children, particularly variables that are sensitive to developmental change and that differentiate typical language children from children with SLI; and b) to describe the acquisition of complex syntax production in children with SLI across an 18-month period beginning at 5 years of age as compared to age-matched typical children and language-matched, but chronologically younger, typical children.

Source & number: Starkey Laboratories – Benjamin Hornsby, Principal Investigator
Title: Variability Among Hearing Aid Users: Speech Recognition in Noise and Benefit from Amplification
Project period: 3/31/08-6/30/09
Description: This project is designed to describe to what extent individual differences in masking and masking release affect listeners' success with amplification, and whether prior knowledge of these differences can improve hearing aid outcomes.

Source & number: Starkey Laboratories – Benjamin Hornsby, Principal Investigator
Title: Hearing Loss, Cognitive Processing and Listening Effort
Project period: 11/1/07-03/31/09
Description: The project focuses on assessing the effects of hearing loss and the potential benefits of various hearing aid interventions on cognitive processing demands and indirectly, listening effort, throughout the day.

Source & number: NIH/1R03DC009488 – Daniel Polley, Principal Investigator
Title: The Auditory Phenotype of Kv channel Gene Mutations
Project period: 02/15/09-01/31/12
Description: The long-term objective of the proposed work is to understand how the intrinsic electrical excitability of neurons in central auditory system contributes to auditory signal processing.

Source & number: National Organization for Hearing Research Foundation – Daniel Polley, Principal Investigator
Title: Restoration of Binaural Integration Following Unilateral Conductive Hearing Loss in Early Life

Project period: 1/25/08-4/30/09
Description: The current proposal seeks to develop a translational neuroscience model to study the effects of conductive hearing loss at the level of the single neuron in the auditory cortex of the awake rat and to develop a novel, highly interactive behavioral remediation strategy that can be used to restore binaural processing to the normative state.

Source & number: Med-El Corporation – D. Wesley Grantham, Principal Investigator
Title: Spatial Hearing in Bilaterally Implanted Cochlear Implant Users, Phase 2
Project period: 2/1/08-1/31/10
Description: The primary objective of this research is to determine the advantage in various listening tasks of having two cochlear implants rather than one.

Source & number: Cochlear Americas – D. Wesley Grantham, Principal Investigator
Title: Spatial Hearing in Patients with the Baha Osseointegrated Cochlear Stimulator
Project period: 9/1/06-8/31/09
Description: The specific aim of the project is to investigate under ideal conditions horizontal-plane localization performance and speech recognition performance in unilaterally hearing-impaired adults who have been fitted with the Baha implantable cochlear stimulator on the side of their poor ear.

Source & number: 5R44DC005526 – Rafael Delgado, Principal Investigator; Linda Hood, Co-Principal Investigator
Title: Fast Audiogram Determination Using ASSR's
Project period: 8/1/06-7/31/09
Description: The objective of this study is to develop a small portable handheld system capable of objectively determining audiogram configurations in infants using auditory steady-state responses (ASSRs).

Source & number: 5T35DC008763– Linda Hood, Principal Investigator
Title: Developing Research Careers in the Hearing Sciences
Project period: 4/1/07-3/31/12
Description: This project is to provide experience in hearing research to pre-doctoral students who are enrolled in a clinically based degree (AuD) programs to develop interest in pursuing a career in hearing research.

Source & number: 2R01MH063861– Mark T. Wallace, Principal Investigator
Title: Development of Multisensory Cortex: Role of Experience
Project period: 8/5/08-5/31/13
Description: This research posits that early postnatal experience plays a critical role in determining the nature of multisensory processes and their consequent impact on perception and behavior.

Source & number: 5R03HD050860—Mark T. Wallace, Principal Investigator
Title: A Multisensory Framework for Developmental Dyslexia
Project period: 7/1/05-6/30/09
Description: The primary goal of this study will serve to further our understanding of the neurophysiological bases of dyslexia.

Source & number: NARSAD Research Grants Program – Mark T. Wallace, Principal Investigator
Title: Multisensory processing Alterations in Schizophrenia
Project period: 9/15/08-9/14/10
Description: The purpose of the research is to designed to provide new insights into the neural underpinnings of this debilitating disease, and to use this knowledge (and the conceptual framework it is based upon) for the development of more effective clinical strategies and interventions.

Source & number: 1R01DC008429—David Zealear, Principal Investigator (Daniel Ashmead, Co-Investigator)
Title: Electrical Stimulation of the Bilaterally Paralyzed Larynx Paced with Respiration
Project period: 8/15/06 - 7/31/11
Description: The goal of this research is to conceive an implantable laryngeal pacemaker system that will re-establish bilateral glottal opening in synchrony with inspiration.

Source & number: 1R21EB006044—Robert F. Labadie, Principal Investigator
Title: Robotic Mastiodectomy
Project period: 8/1/07 - 7/31/09
Description: This project's objective is to investigate the use of a computer-controlled, autonomous, robot to perform a specified surgical procedure – mastoidectomy.

Source & number: 1R01DC008408—Robert F. Labadie, Principal Investigator
Title: Clinical Validation and Testing of Percutaneous Cochlear Implantation
Project period: 4/1/07 - 3/31/11
Description: This project's objective is to investigate the use of image guided surgical (IGS techniques.

Source: American Academy of Otolaryngology—Sarah Rohde, Principal Investigator
Title: The Role of VEGF in Isolated Cleft Palate
Project period: 7/1/07 - 6/301/08
Description: The project is to identify genes that interact with vascular endothelial growth factor (VEGF), a molecule that has been implicated in the assembly of the primitive vascular network.

Source: Cochlear Americas—David Haynes, Principal Investigator
Title: Fluorescence of the Facial Nerve In Vivo
Project period: 4/1/04 - 3/31/09
Description: This project's objectives are to enhance the visibility of the facial nerve using fluorescence in order to facilitate placement of cochlear implants in patients with potentially abnormal facial nerve anatomy and to develop a simple, affordable display system that readily allows incorporation of the fluorescence techniques into the existing operating room technology.

Source: American Academy of Otolaryngology—Steven Goudy, Principal Investigator
Title: Irf6 is Critical in Palate Development and Interacts with Fgf8, FgF10 & Tbx1
Project period: 8/1/07 - 7/31/09
Description: The projects objectives is to determine whether Irf6 affects apoptosis, cell proliferation or differentiation during palate development and to determine whether there is a direct genetic interaction between Irf6, Fgf10, Tbx1, and Fgf8 during palate development.

Source & number: 1K08DE017953 —Steven Goudy, Principal Investigator
Title: The Role of IRF6 during Craniofacial Development
Project period: 08/1/08-07/31/13
Description: The objective of this research is to identify the function of genes critical to palatal formation

Source & number: 1R03DC008400—Bernard Rousseau, Principal Investigator
Title: Effect of Vocalization on Tissue Protein Levels in the Acute Vocal Fold Wound
Project period: 4/1/07 - 3/31/10
Description: The long-term objective of this line of research is to understand how vocalization influences organization and remodeling of the injured vocal fold.

Source & number: 1R21DC009873 – Bernard Rousseau, Principal Investigator
Title: Growth Factor Treatment for Aged Vocal Folds
Project period: 12/04/08-11/30/10
Description: The long term goal is to develop treatments that target gene expression mediated synthesis and degradation of the aged vocal fold.

Source & number: R01DC007453 – Subcontract with Massachusetts Eye and Ear Infirmary -- Roland Eavey, Co-Principal Investigator
Title: The Role of Eya4in Hearing and Disease
Project period: 03/1/09-06/30/11
Description: The focus of this project is on sensorineural hearing loss and otitis media. The long-term goal is to provide fundamental new information

about the molecular basis for normal audition as well as hearing loss. In addition, these investigations may enlighten how gene-environment interactions increase otitis media susceptibility, a common contributor to human hearing loss.

Source & number: 5R01 DE013173-07 (NIH/NIDCR) – Wendell Yarbrough Principal Investigator
Title: Novel Protein Regulator of Tumor Suppressor ARF & NF-kB
Project period: 05/01/05-4/30/10
Description: This project will characterize a novel protein (LZAP) that binds and alters ARF, p53, and NF-kB activity

Source: Shire Pharmaceuticals – Michael G. Tramontana, Principal Investigator
Title: Psychostimulant Treatment of TBI-Related Attention Deficits: fMRI Analysis of Neural Mechanisms of Response
Project period: 06/1/09 – 8/31/10
Description: This project will apply fMRI to examine possible modes of positive action involving stimulant medication in the treatment of traumatic brain injury (TBI) – acquired attention deficits. This study is the first controlled study of stimulant treatment for TBI-acquired attention deficits using a medication option other than methylphenidate.

PENDING SUPPORT

Source & number: 1R01DC009836 —Daniel Polley, Principal Investigator
Title: Activity-Dependent Influences on Auditory Circuits
Project period: 07/1/09-06/30/14
Description: The overall goal of the project is to better understand the impact of degraded auditory experience on brain function, the mechanisms by which these changes occur, and the potential to reverse the expression of these changes through auditory remediation protocols.

Source & number: DOE – Melanie Schuele, Principal Investigator
Title: Enhancing the Preparation of Speech-Language Pathologists to Collaboratively Address the Language and Literacy Needs of Children with Disabilities
Project period: 07/1/09-06/30/13
Description: The purpose of this project is to provide specialized training in language and literacy to trainees in speech-language pathology.

Source & number: DOE – P. Lynn Hayes, Principal Investigator
Title: Project D.E.A.F: Developing Educator of the Deaf – Aiming for the Future
Project period: 07/1/09-06/30/13

Description: The purpose of this project is to train and graduate doctoral level educators of the deaf to assume leadership positions in teaching, research, and administration in auditory/oral programs serving infants and young children who are deaf or hard of hearing.

Source & number: NIH – Terrie Gibson, Principal Investigator
Title: Differential motor Control in Speech Productions of Children with DS
Project period: 12/1/09-11/30/12
Description: The study is designed to describe two aspects of speech production in DS; coarticulation patterns and F2 variability for stop place of articulation.

Source & number: 2R01DC000523-14A1 – Edward G. Conture, Principal Investigator
Title: Emotional and Linguistic Conributions to Developmental Stuttering
Project period: 12/1/09-11/30/14
Description: The purpose of this study is to propose a longitudinal study of preschool-age children who stutter, with emphasis on how emotion and speech-language processes contribute to developmental stuttering.

Source & number: 2R01DC010184-01A1 – Robert F. Labadie, Principal Investigator
Title: Pediatric Percutaneous Cochlear Implantation Clinical Validation & implementation
Project period: 12/1/09-11/30/13
Description: This study is designed to access the inner ear, specifically the cochlea, which is currently required for cochlear implant (CI) surgery, in which an electrode array is used to stimulate the auditory nerve and allow deaf people to hear. This study proposes to translate this technology to the pediatric population.