PI: **Walker, Elizabeth A.**	Title: Mechanisms of Listening Effort in School Age Children who are Hard of Hearing	
Received: 10/24/2016	FOA: PAR16-057	Council: 05/2017
Competition ID: FORMS-D	FOA Title: NIDCD EARLY CAREER RESEARCH (ECR) AWARD (R21)	
1 R21 DC015832-01A1	Dual:	Accession Number: 3986867
IPF: 3972901	Organization: UNIVERSITY OF IOWA	
Former Number:	Department: Communication Sciences Disor	
IRG/SRG: CDRC	AIDS: N	Expedited: N
Subtotal Direct Costs (excludes consortium F&A) Year 1: [redacted] Year 2: [redacted] Year 3: [redacted]	Animals: N Humans: Y Clinical Trial: N Current HS Code: 30 HESC: N	New Investigator: Early Stage Investigator:
Senior/Key Personnel:	*Organization:*	*Role Category:*
Elizabeth Walker Ph.D.	University of Iowa	PD/PI
Jacob Oleson Ph.D.	University of Iowa	Co-Investigator
[redacted]	University of Iowa	Consultant
[redacted]	Linkoping University	Consultant

OMB Number 4040-0001
Expiration Date 06/30/2016

APPLICATION FOR FEDERAL ASSISTANCE
SF 424 (R&R)

3. DATE RECEIVED BY STATE		**State Application Identifier**
1. TYPE OF SUBMISSION*	**4.a. Federal Identifier** DC015832	
❍ Pre-application ● Application ❍ Changed/Corrected Application	**b. Agency Routing Number**	
2. DATE SUBMITTED 2016-10-24	**Application Identifier**	**c. Previous Grants.gov Tracking Number**

5. APPLICANT INFORMATION **Organizational DUNS*:** [redacted]

Legal Name*: University of Iowa
Department:
Division:
Street1*: [redacted]
Street2:
City*: [redacted]
County:
State*: [redacted]
Province:
Country*: USA: UNITED STATES
ZIP / Postal Code*: [redacted]

Person to be contacted on matters involving this application
Prefix: First Name*: Jennifer Middle Name: L. Last Name*: Lassner Suffix:
Position/Title: Assistant Vice President for Research
Street1*: [redacted]
Street2:
City*: [redacted]
County:
State*: [redacted]
Province:
Country*: USA: UNITED STATES
ZIP / Postal Code*: [redacted]
Phone Number*: [redacted] Fax Number: [redacted] Email: [redacted]

6. EMPLOYER IDENTIFICATION NUMBER *(EIN) or (TIN)** [redacted]

7. TYPE OF APPLICANT* H: Public/State Controlled Institution of Higher Education

Other (Specify):
Small Business Organization Type ❍ Women Owned ❍ Socially and Economically Disadvantaged

8. TYPE OF APPLICATION*
❍ New ● Resubmission
❍ Renewal ❍ Continuation ❍ Revision

If Revision, mark appropriate box(es).
❍ A. Increase Award ❍ B. Decrease Award ❍ C. Increase Duration
❍ D. Decrease Duration ❍ E. Other *(specify)* :

Is this application being submitted to other agencies?* ❍Yes ●No What other Agencies?

9. NAME OF FEDERAL AGENCY*
National Institutes of Health

10. CATALOG OF FEDERAL DOMESTIC ASSISTANCE NUMBER
TITLE:

11. DESCRIPTIVE TITLE OF APPLICANT'S PROJECT*
Mechanisms of Listening Effort in School Age Children who are Hard of Hearing

12. PROPOSED PROJECT
Start Date* Ending Date*
07/01/2017 06/30/2020

13. CONGRESSIONAL DISTRICTS OF APPLICANT
IA-002

SF 424 (R&R) APPLICATION FOR FEDERAL ASSISTANCE — Page 2

14. PROJECT DIRECTOR/PRINCIPAL INVESTIGATOR CONTACT INFORMATION

Prefix: Dr. First Name*: Elizabeth Middle Name: A. Last Name*: Walker Suffix: Ph.D.
Position/Title: Assistant Professor
Organization Name*: University of Iowa
Department: Communication Sciences Disor
Division: College of Liberal Arts & Sci
Street1*: [redacted]
Street2:
City*: [redacted]
County: [redacted]
State*: [redacted]
Province:
Country*: USA: UNITED STATES
ZIP / Postal Code*: [redacted]
Phone Number*: [redacted] Fax Number: Email*: [redacted]

15. ESTIMATED PROJECT FUNDING

a. Total Federal Funds Requested* [redacted]
b. Total Non-Federal Funds* [redacted]
c. Total Federal & Non-Federal Funds* [redacted]
d. Estimated Program Income* [redacted]

16. IS APPLICATION SUBJECT TO REVIEW BY STATE EXECUTIVE ORDER 12372 PROCESS?*

a. YES ❍ THIS PREAPPLICATION/APPLICATION WAS MADE AVAILABLE TO THE STATE EXECUTIVE ORDER 12372 PROCESS FOR REVIEW ON:

DATE:

b. NO ● PROGRAM IS NOT COVERED BY E.O. 12372; OR

❍ PROGRAM HAS NOT BEEN SELECTED BY STATE FOR REVIEW

17. By signing this application, I certify (1) to the statements contained in the list of certifications* and (2) that the statements herein are true, complete and accurate to the best of my knowledge. I also provide the required assurances * and agree to comply with any resulting terms if I accept an award. I am aware that any false, fictitious, or fraudulent statements or claims may subject me to criminal, civil, or administrative penalties. (U.S. Code, Title 18, Section 1001)

● I agree*

** The list of certifications and assurances, or an Internet site where you may obtain this list, is contained in the announcement or agency specific instructions.*

18. SFLLL or OTHER EXPLANATORY DOCUMENTATION File Name:

19. AUTHORIZED REPRESENTATIVE

Prefix: First Name*: Daniel Middle Name: A. Last Name*: Reed Suffix: Ph.D.
Position/Title*: Vice President for Research
Organization Name*: University of Iowa
Department: Office of the VP for Research
Division:
Street1*: [redacted]
Street2:
City*: [redacted]
County: [redacted]
State*: [redacted]
Province:
Country*: USA: UNITED STATES
ZIP / Postal Code*: [redacted]
Phone Number*: 319-335-2123 Fax Number: [redacted] Email*: [redacted]

Signature of Authorized Representative* [redacted]

Date Signed* 10/24/2016

20. PRE-APPLICATION File Name:

21. COVER LETTER ATTACHMENT File Name:cover_letter1030133272.pdf

424 R&R and PHS-398 Specific
Table Of Contents

OMB Number: 4040-0010
Expiration Date: 06/30/2016

Project/Performance Site Location(s)

Project/Performance Site Primary Location

❍ I am submitting an application as an individual, and not on behalf of a company, state, local or tribal government, academia, or other type of organization.

Organization Name: University of Iowa
Duns Number: [redacted]
Street1*: [redacted]
Street2:
City*: [redacted]
County:
State*: [redacted]
Province:
Country*: USA: UNITED STATES
Zip / Postal Code*: [redacted]
Project/Performance Site Congressional District*: [redacted]

File Name

Additional Location(s)

OMB Number: 4040-0001
Expiration Date: 06/30/2016

RESEARCH & RELATED Other Project Information

1. Are Human Subjects Involved?* ● **Yes** ❍ **No**

1.a. If YES to Human Subjects

Is the Project Exempt from Federal regulations? ❍ Yes ● No

If YES, check appropriate exemption number: __ 1 __ 2 __ 3 __ 4 __ 5____6

If NO, is the IRB review Pending? ❍ **Yes** ● **No**

IRB Approval Date: 08-04-2016

Human Subject Assurance Number 00003007

2. Are Vertebrate Animals Used?* ❍ **Yes** ● **No**

2.a. If YES to Vertebrate Animals

Is the IACUC review Pending? ❍ Yes ❍ No

IACUC Approval Date:

Animal Welfare Assurance Number

3. Is proprietary/privileged information included in the application?* ❍ **Yes** ● **No**

4.a. Does this project have an actual or potential impact - positive or negative - on the environment?* ❍ **Yes** ● **No**

4.b. If yes, please explain:

4.c. If this project has an actual or potential impact on the environment, has an exemption been authorized or an environmental assessment (EA) or environmental impact statement (EIS) been performed? ❍ Yes ❍ No

4.d. If yes, please explain:

5. Is the research performance site designated, or eligible to be designated, as a historic place?* ❍ **Yes** ● **No**

5.a. If yes, please explain:

6. Does this project involve activities outside the United States or partnership with international collaborators?* ❍ **Yes** ● **No**

6.a. If yes, identify countries:

6.b. Optional Explanation:

	Filename
7. Project Summary/Abstract*	LE_Project_Summary_Abstract1030133132.pdf
8. Project Narrative*	Project_narrative1029105141.pdf
9. Bibliography & References Cited	LE_References1030133134.pdf
10.Facilities & Other Resources	LE_RESOURCES1029365405.pdf
11.Equipment	LE_Equipment1029105142.pdf

ABSTRACT

Many children with mild to severe hearing loss are identified and receive early intervention at very young ages. Even with this early intervention, however, children who are hard of hearing (CHH) experience challenges with communication due to reduced access to the auditory signal. These challenges are further compounded in school because CHH have increased difficulty perceiving speech in adverse acoustic conditions and most listening conditions are characterized by poor acoustics. When listening in adverse conditions, CHH must exert additional cognitive resources compared to children with normal hearing (CNH) in order to perceive an incoming message. Consequently, they have fewer cognitive resources available to perform additional tasks and must expend increased listening effort. Listening effort requires the coordination of low-level, bottom-up processes, and higher-level, top-down processes. There is a lack of evidence regarding the interplay between auditory access and higher-level cognitive skills in influencing individual differences in listening effort for CHH. This knowledge gap hinders the understanding of the underlying mechanisms that drive listening effort in children with hearing loss, which in turn, limits the ability to develop evidence-based interventions for this population. The current proposal seeks to determine the factors that underlie increased listening effort in school-age CHH. This proposal is based on a limited resources capacity theory, which posits that listeners require additional cognitive resources to maintain optimal listening performance during adverse acoustic conditions, and this demand on resources results in a decline in performance on secondary tasks. Specifically, the current proposal tests the hypothesis that top-down processing, quantified by working memory and linguistic skills, is associated with listening effort in school-age CHH, and this relationship is moderated by bottom-up processing, measured via aided audibility. Two specific aims are proposed to test this hypothesis: Aim 1. To determine the effect of higher-level cognitive-linguistic skills on listening effort in school-age children who are hard of hearing, and to evaluate the extent to which auditory access influences the relationship between cognitive-linguistic skills and listening effort. Aim 2. To identify the effects of hearing aid use and background noise on listening effort in children who are hard of hearing. In Aim 1, working memory capacity, receptive vocabulary, and aided speech audibility will be used to predict listening effort in varying levels of background noise. In Aim 2, listening effort for CHH will be evaluated in aided and unaided conditions, in quiet and in background noise. In both aims, different dimensions of listening effort will be captured, including reaction time, self-report measures, and speech recognition performance. The data generated from this proposal will inform theoretical models regarding the integration of low-level, acoustic-phonetic input and higher-level, cognitive-linguistic processes involved in listening, using a mechanistic approach to examine listening effort. The proposed study will also provide empirical evidence for the development of effective interventions for children with hearing loss, in both classroom and social settings.

PROJECT NARRATIVE

The purpose of this research proposal is to identify the underlying mechanisms that influence listening effort in degraded acoustic environments with school-age children who have mild to severe hearing loss. The proposed research is relevant to public health because it will provide important insights into how children manage listening demands in complex auditory environments. This project is highly related to the NIH's mission because the data will guide evidence-based practice and policy for the clinical and educational management of children who are hard of hearing.

FACILITIES AND OTHER RESOURCES
Mechanisms of Listening Effort in School-Age Children who are Hard of Hearing

UNIVERSITY OF IOWA

Environment – Contribution to Success

The PD/PI and her research team have access to facilities and equipment at the primary performance site that will facilitate successful initiation and completion of the proposed research project. The PI has used her start-up money to purchase equipment and standardized tests in her laboratory that will support the aims of this project. The PI also has set up her laboratory to allow for face-to-face video conferencing to maximize interactions with the overseas consultant, Dr. Rudner. The PI has long-standing collaborations with a number of extramurally funded investigators who are doing research that is related to the stated aims of the proposed project.

Institutional Commitment to the Early Stage Investigator

The Department of Communication Sciences and Disorders and the University of Iowa will provide substantial institutional support to the PI as an Early Stage Investigator (ESI). Dr. Walker is currently in the second year of a 9-month, tenure-track appointment. Her current teaching load consists of one course per semester and no summer teaching. The start-up package at the University of Iowa provided laboratory space, office space, equipment, and research funds to support the initiation of her research program. The start-up funds also covered initial funding for a PhD-level research assistant and an hourly employee, which enabled collection of the preliminary data included in the Approach section of the proposal. The Department of Communication Sciences and Disorders includes senior faculty members with a successful history of extramural funding, who will provide intellectual support through ongoing research discussions, daily interactions, and internal reviews of manuscripts and grant writing. The university offers career development training including grant-writing and professional speaking workshops. In addition, the university provides web-based courses and university-based services on ethical conduct of research. The PI's department provides administrative support through a departmental administrative core.

Facilities

Laboratories:

Pediatric Audiology Laboratory. The Pediatric Audiology Laboratory is housed in the Wendell Johnson Speech and Hearing Center in the Department of Communication Sciences and Disorders at the University of Iowa. The laboratory is under the direction of Dr. Elizabeth Walker. It consists of one large room that has been divided into smaller office modules for data entry personnel. Within the laboratory space, there is a large double-walled sound-treated booth that will be used for data collection from the research participants. The examination room is equipped with a clinical GSI-61 audiometer with speakers, supra-aural and insert earphones, two portable audiometers with supra-aural and insert earphone and bone vibrators, a GSI Tympstar tympanometer, a portable Welch Allyn Microtymp 2 tympanometer, two Audioscan Verifit probe microphone systems for presentation and analysis of stimuli in the ear canal, and two otoscopes. *The laboratory facilities and equipment have been designed to facilitate the development of a programmatic research plan, of which the proposed project is the next step.*

Audibility, Perception and Cognition Laboratory. For data collection in the western Iowa/Nebraska area, we will use a second site at Boys Town National Research Hospital in Omaha, NE. The laboratory is located in the Lied Learning and Technology Center, a child-friendly clinical, research and outreach facility. This laboratory is under the direction of Dr. Ryan McCreery. The lab includes a large double-walled sound-treated booth. The laboratory is equipped with three Windows-based computers having 24-bit A/D and D/A capabilities and a variety of analog devices. Software-based signal processing is available through external sound cards (MOTU Track 16) on the primary lab computer. A laptop computer is used to program and adjust hearing aids and is equipped with NOAH database and wireless programming capabilities. The laboratory also contains a clinical audiometer, tympanometer, CD player, and a variety of transducers, including supra-aural and insert earphones, bone vibrators, and four loudspeakers. Probe-microphone systems (Audioscan Verifit) for recording and analysis of stimuli in the ear canal are available. Specialized software is available for implementing psychoacoustic paradigms, measuring acoustic stimuli, and analyzing data.

Heartland Area Education Agency (AEA). For data collection in the central part of Iowa, the PI will have access to a third site that is situated at the Heartland AEA in Johnston, IA, located outside Des Moines, IA. This site is equipped with a double-walled, sound treated booth, a clinical audiometer, tympanometer, and otoscope. There is a visual reinforcement system and a variety of transducers, including supra-aural and insert earphones, bone vibrators, and loudspeakers. There are also additional small conference rooms that are utilized for speech and language data collection, as well as a family-friendly waiting room.

Animal: Not Applicable

Office

The PI's office space is located two floors below the laboratory space. It contains hardwired high-speed Internet access, as well as Internet access via the university's wireless Eduroam network. *These facilities provide the PI with access to the space needed to develop research protocols, analyze data, prepare manuscripts, and disseminate findings.*

Computer

Facilities: All networking and file servers are provided by and maintained by the University of Iowa's Information Technology Service. The file servers are housed in a standard computer facility with security and fire control. The file servers are equipped with a backup system, and the U of Iowa ITS routinely provides sequential backup.

Networking: Work stations are all connected via high speed Ethernet to the remote file servers and also provide connections to Internet. Internet connectivity facilitates communication with other research centers and enables direct access to the library system that provides on-line access to Medline, ERIC, and Psychlit as well as electronic copies of most journal articles.

PCs: Dr. Walker's laboratory is equipped with three Windows-based Dell personal computers, two Dell laptop computers, and two Surface laptops. The laboratory computers share an HP LaserJet Pro 400 printer as a network printer. This network provides the laboratory staff with access to a full complement of software that includes: PC-SAS and R for Windows, MPlus, Sigma Plot, Matlab, Adobe Audition and Audacity.

Telecommunications: The PI has access to Skype and Zoom technology that allows the use of high speed Internet II connections for video conferencing with the project consultant. The laboratory has a large monitor with HDMI capabilities to allow for video teleconferencing via Skype with the project consultant and other intellectual collaborators.

Other Resources:

Data management and analysis. The Center for Public Health Statistics is a collegiate research and service center in the College of Public Health and will provide support for data management and analysis for this project. Research in the CPHS includes collaborative projects from a variety of funding sources and over a broad array of public health concerns. Part of the mission of the Center is to facilitate access to major databases that are useful in health-related research, such as those produced by the Census Bureau and National Center for Health Statistics. The Center is located in a suite of eight rooms in the Westlawn building, on the health sciences campus. Four secured data servers and one web server are maintained to hold and transfer protected health data, as well as the usual assortment of desktop machines, printers, copy machine, etc. for the staff. The servers are securely housed in the collegiate central IT server room, and are managed by the collegiate IT staff, under the direction of Mr. Tim Shie.

Intellectual Resources/Useful Collaborations. The individuals listed below are NIH-funded principal investigators in the PI's research environment who are doing research that is complementary to the proposed project. The PI has a longstanding collaboration with these investigators. *They provide invaluable constructive criticism and intellectual resources, which will greatly contribute to the success of this project.*

INVESTIGATOR	AGENCY	GRANT NUMBER	TITLE
Dr. Ryan McCreery	NIH/NIDCD	R01 DC009560	Complex Listening Skills in School-Age Hard of Hearing Children
Dr. Mary Pat Moeller	NIH/NIDCD	R01 DC013591	Outcomes of School-Age Children who are Hard of Hearing
Dr. J. Bruce Tomblin	NIH/NIDCD	R01 DC013591	Outcomes of School-Age Children who are Hard of Hearing

Drs. McCreery and Moeller have positions at Boys Town National Research Hospital in Omaha, NE. Dr. Tomblin is an emeritus professor at the University of Iowa, in the PI's department. The PI has served as an investigator on several NIH-funded grants with all three of these researchers, and has co-authored peer-reviewed papers with them. The PI has a bimonthly video conference call with the three investigators, and weekly contact via telephone and email.

Mechanisms of Listening Effort in School-Age Children who are Hard of Hearing

Equipment

The Resources section described a range of equipment that would support the research mission. Specific to this project is equipment needed to measure hearing in children and evaluate hearing aids. The children seen in this project will be primarily served in two locations. Here I describe the equipment at the primary and secondary centers.

University of Iowa

Children will be seen in the Pediatric Audiology Laboratory at the University of Iowa. This laboratory has three audiometers, two tympanometers, hearing aid fitting instruments including two Audioscan Verifit real ear systems, Biologic AudX automated OAE system, and otoscope.

Boys Town National Research Hospital

BTNRH has both laboratory and clinical facilities for audiological studies. In these settings are 4 double-walled sound-treated booths, several audiometers, tympanometers, OAE systems, as well as equipment for Computerized Play Audiometry and Video Visual Reinforcement audiometry systems, and CD players. Hearing aid fitting instruments include probe microphone/hearing-aid analyzers.

OMB Number. 4040-0001
Expiration Date: 06/30/2016

RESEARCH & RELATED Senior/Key Person Profile (Expanded)

PROFILE - Project Director/Principal Investigator

Prefix: Dr. First Name*: Elizabeth Middle Name A. Last Name*: Walker Suffix: Ph.D

Position/Title*: Assistant Professor
Organization Name*: University of Iowa
Department: Communication Sciences Disor
Division: College of Liberal Arts & Sci
Street1*:
Street2: [redacted]
City*: [redacted]
County:
State*:
Province:
Country*: USA: UNITED STATES
Zip/ Postal Code*:

Phone Number*: [redacted] Fax Number:

E-Mail*: elizabeth-walker@uiowa.edu

Credential, e.g., agency login: [redacted]

Project Role*: PD/PI Other Project Role Category:

Degree Type: Ph.D. Degree Year: 2010

Attach Biographical Sketch*: File Name: BIO_Walker_20161030029035.pdf

Attach Current & Pending Support: File Name:

PROFILE - Senior/Key Person

Prefix: Dr. First Name*: Jacob Middle Name J. Last Name*: Oleson Suffix: Ph.D

Position/Title*: Associate Professor
Organization Name*: University of Iowa
Department: Biostatistics
Division: College of Public Health
Street1*: [redacted]
Street2:
City*: [redacted]
County:
State*:
Province:
Country*: USA: UNITED STATES
Zip / Postal Code*: [redacted]

Phone Number*: [redacted] Fax Number:

E-Mail*: [redacted]

Credential, e.g., agency login: [redacted]

Project Role*: Co-Investigator Other Project Role Category:

Degree Type: Ph.D. Degree Year: 2002

Attach Biographical Sketch*: File Name: Bio_Oleson1029365380.pdf

Attach Current & Pending Support: File Name:

PROFILE - Senior/Key Person

Prefix: Dr. First Name*: [redacted] Middle Name Last Name*: [redacted] Suffix: Ph.D

Position/Title*: Assistant Professor
Organization Name*: University of Iowa
Department: Communication Sciences Disor
Division: College of Liberal Arts & Sci
Street1*: [redacted]
Street2:
City*: [redacted]
County:
State*:
Province:
Country*: USA: UNITED STATES
Zip / Postal Code*: [redacted]

Phone Number*: [redacted] Fax Number:

E-Mail*: [redacted]

Credential, e.g., agency login: [redacted]

Project Role*: Consultant Other Project Role Category:

Degree Type: Ph.D. Degree Year: 2007

Attach Biographical Sketch*: File Name: Bio_[redacted]1029365373.pdf

Attach Current & Pending Support: File Name:

PROFILE - Senior/Key Person				
Prefix: Dr.	First Name*: [redacted]	Middle Name	Last Name*: [redacted]	Suffix: Ph.D

Position/Title*: Assistant Professor
Organization Name*: Linkoping University
Department: Behavioural Sciences and Learn
Division:
Street1*: [redacted]
Street2:
City*:
County:
State*:
Province:
Country*: [redacted]
Zip / Postal Code*:

Phone Number*: [redacted] Fax Number:

E-Mail*: [redacted]

Credential, e.g., agency login:

Project Role*: Consultant Other Project Role Category:

Degree Type: Ph.D. Degree Year: 2005

Attach Biographical Sketch*: File Name: Biosketch_[redacted]1030133183.pdf

Attach Current & Pending Support: File Name:

BIOGRAPHICAL SKETCH

Provide the following information for the Senior/key personnel and other significant contributors in the order listed on Form Page 2.
Follow this format for each person. **DO NOT EXCEED FIVE PAGES.**

NAME Walker, Elizabeth A.	POSITION TITLE Assistant Professor
eRA COMMONS USER NAME (credential, e.g., agency login) [redacted]	

EDUCATION/TRAINING *(Begin with baccalaureate or other initial professional education, such as nursing, include postdoctoral training and residency training if applicable.)*

INSTITUTION AND LOCATION	DEGREE *(if applicable)*	MM/YY	FIELD OF STUDY
University of Iowa, Iowa City, IA	B.A.	05/99	Psychology, Speech and Hearing Science
University of Minnesota, Minneapolis, MN	M.A.	05/02	Communication Disorders
University of Iowa, Iowa City, IA	Ph.D.	05/10	Speech and Hearing Science

A. Personal Statement.

My role in this project is that of PD/PI. I am an Early Stage Investigator submitting my R21 Early Career Research Award application. The focus of the current research proposal is to investigate the underlying mechanisms of listening effort in children who are hard of hearing. The participants will be children with mild-to-severe hearing loss and an age-matched comparison group of children with normal hearing. Specifically, I propose to test the hypothesis that working memory and linguistic skills are associated with listening effort in school-age children who are hard of hearing, and this relationship is moderated by bottom-up processing, measured via aided audibility. Given my past clinical and research experiences, I am exceptionally well-qualified to lead this project. The base of expertise needed to carry out the proposed research started with my master's thesis, under the mentorship of Drs. Arlene Carney and Ben Munson, which focused on how cognitive (nonverbal IQ) and linguistic abilities (expressive and receptive vocabulary) influence speech perception in adults with cochlear implants. For that work, I received an Editors' award from the *Journal of Speech, Language, and Hearing Research.* Following this experience, I obtained dual certification as a speech-language pathologist and audiologist. I have worked with children with hearing loss over the past 15 years, first as a research associate in the Devault Otologic Research Laboratory at Indiana University. In this capacity, I worked under Drs. David Pisoni and Karen Kirk in their investigation of the underlying neuropsychological processes that influence listening and language outcomes in children with cochlear implants. More recently, I have gained valuable experience as an investigator on the following NIH-funded projects: Outcomes of Children with Hearing Loss, Outcomes of School-Age Children who are Hard of Hearing, and Complex Listening in School-Age Children who are Hard of Hearing. During this time, I have been actively involved in data collection, subject recruitment, data analysis, interpretation, dissemination and continuing reviews for all grants. I have 24 peer-reviewed manuscript publications (with two additional papers recently accepted). My median Relative Citation Ratio is 5.9, indicating that my manuscripts have had a high impact within the context of my research field. I have developed an extensive network for subject recruitment, through my contacts with pediatric audiologists in the state of Iowa, and my ongoing relationship with researchers at Boys Town National Research Hospital. For the proposed project, I also have the intellectual support of collaborators ([redacted] who provide essential expertise in cognitive hearing science, which is complementary to my own expertise in aural habilitation and language development. In summary, my past endeavors have provided me with a unique perspective on the intersection of language, hearing, and cognition that will contribute to the stated research plan and objectives and support my role as principal investigator on this project.

B. Positions and Honors.

Positions and Employment

1997-1999 Research Assistant, University of Iowa, Department of Psychology, Principal Investigators: Jodie Plumert and Grazyna Kochanska

Biographical Sketch: Walker, E.A.

2002-2004	Clinical Research Associate, Devault Otologic Research Laboratory, Indiana University School of Medicine, Principal Investigator: Richard T. Miyamoto
2003-2004	Audiology Clinical Fellowship, Riley Hospital, Indianapolis, IN
2006-2010	Research Associate, Children's Cochlear Implant Project, University of Iowa, Principal Investigator: Bruce J. Gantz
2008-2010	Research Associate, University of Iowa, Department of Communication Sciences and Disorders, Principal Investigators: J. Bruce Tomblin and Mary Pat Moeller
2010-	Investigator, Children's Cochlear Implant Project, University of Iowa, Principal Investigator: Bruce J. Gantz
2010-	Investigator, University of Iowa, Department of Communication Sciences and Disorders, Principal Investigators: J. Bruce Tomblin and Mary Pat Moeller
2011	Adjunct Faculty, Department of Communication Sciences and Disorders, Augustana College, Rock Island, IL
2015-	Assistant Professor, Department of Communication Sciences and Disorders, University of Iowa

Other Experience and Professional Memberships

2004- American Speech-Language-Hearing Association
- Topic Committee Member, American Speech-Language-Hearing Association Annual Meeting, 2012-2015
- Topic Chair, Intervention/Rehabilitation for Infants and Children with Hearing Loss, Tinnitus or Balance Disorder, American Speech-Language-Hearing Association Annual Meeting, 2016-present

2008- Board member, AG Bell of Iowa
- Public Relations Director, 2013-present

2012- American Auditory Society

2013- American Cochlear Implant Alliance

Ad-hoc Reviewer: Pediatrics; Ear and Hearing; Journal of Speech, Language, and Hearing Research; American Journal of Audiology; American Journal of Speech-Language Pathology; International Journal of Audiology; Journal of Communication Disorders; Language, Speech, and Hearing Services in Schools; Journal of Educational Audiology; Otology and Neurotology; Applied Cognitive Psychology

Honors

1999	Robert G. Robinson Audiology Scholarship, University of Minnesota
2000	Minnesota Speech and Hearing Foundation Scholarship
2000	American Speech-Language-Hearing Foundation Scholarship
2001	Outstanding Teaching Assistant Award, Mortar Board Honor Society
2004-2008	Presidential Graduate Research Fellowship, University of Iowa
2004	Editors' Award for Best Paper in the area of Hearing, Journal of Speech, Language and Hearing Research
2006	New Century Scholars Doctoral Scholarship, American Speech-Language-Hearing Foundation
2007, 2009	Symposium for Research on Child Language Disorders Student Travel Award
2013	Editors' Award for Best Paper, American Journal of Audiology
2016	Old Gold Fellowship, University of Iowa
2016	Special Recognition, Ear and Hearing Supplement 1 (2015), "The Outcomes of Children with Hearing Loss Study," American Auditory Society

Biographical Sketch: Walker, E.A.

C. Contribution to Science.

1. **The role of lexical characteristics on speech perception skills in adults with cochlear implants.** These publications found that adults with cochlear implants appear to be less sensitive to word frequency and neighborhood density effects compared to age-matched adults with typical hearing.
    a. Munson, B., Donaldson, G.S., Allen, S.L., Collison (Walker), E.A. & Nelson, D.A. (2003). Patterns of phoneme perception errors by listeners with cochlear implants as a function of overall speech perception ability. *Journal of the Acoustical Society of America, 113.* 925-935. [Public Access Compliance – N/A, accepted prior to 4/7/08]
    b. Collison (Walker), E.A., Munson, B. & Carney, A.E. (2004). Relations among linguistic and cognitive skills and spoken word recognition in adults with cochlear implants. *Journal of Speech, Language, and Hearing Research, 47*, 496-508. [Public Access Compliance – N/A, accepted prior to 4/7/08]

2. **Underlying mechanisms that influence speech and language outcomes in children with cochlear implants**. My doctoral work focused on early canonical babbling productions and novel word learning in this population. Using a dynamic word learning paradigm, I showed that lexical acquisition is heavily influenced by extant vocabulary size for children with cochlear implants. Children with cochlear implants perform similarly to their vocabulary-matched peers with typical hearing in terms of fast mapping, word extension and word retention, and are delayed with respect to these variables compared to their same-age peers with typical hearing. Age at implantation does not appear to play a significant role in word learning abilities after controlling for the effect of vocabulary size, for children implanted before 4 years of age. In addition, I made major contributions to manuscripts associated with the University of Iowa Cochlear Implant NIH P50 grants, focusing on the influence of age at implantation on language outcomes and functional outcomes of children with cochlear implants.
    a. Walker, E.A. & Bass-Ringdahl, S.M. (2008). Babbling complexity and its relationship to speech and language outcomes in children with cochlear implants. *Otology and Neurotology, 28,* 225-229. [Public Access Compliance – N/A, accepted prior to 4/7/08]
    b. Walker, E.A. & McGregor, K.K. (2012). Word learning processes in children with cochlear implants. *Journal of Speech, Language, and Hearing Research. 56,* 375-387. [PMCID: PMC3578980]
    c. Dunn C.C., Walker, E., Oleson, J., Kenworthy, M., Van Voorst, T., Tomblin, J.B, Ji, H., Kirk, K., McMurray, B., Hansen, M., & Gantz, B. (2013). Longitudinal speech perception and language performance in pediatric cochlear implant users: the effect of age at implantation. *Ear and Hearing,* 35, 148-160. [PMCID: PMC3944377]
    d. Gantz, B. J., Dunn, C. C., Walker, E. A., Kenworthy, M., Van Voorst, T., Tomblin, B., & Turner, C. (2010). Bilateral cochlear implants in infants: A new approach—Nucleus Hybrid S12 project. *Otology & Neurotology, 31*(8), 1300-1309. [PMCID: PMC2951013]

3. **Understanding and improving access to audiologic services for children with hearing loss.** The focus of my current research involves examination of variations in auditory access for children who are hard of hearing. I have published manuscripts related to timeliness in service provision for children who are hard of hearing. One paper found that over a third of our sample who were later-identified with hearing loss received early intervention services for reasons other than hearing loss, and the average age at hearing loss confirmation for these children was 12 months after they started intervention. This finding supports the need for hearing screenings as part of the evaluation process for Part C services in IDEA, regardless of whether or not hearing loss is the primary reason for referral. I have also explored variations in auditory input based on the amount of daily hearing aid use by children. These studies showed that children with milder degrees of hearing loss, younger children, and mothers with lower education levels were less likely to wear hearing aids on a consistent basis, compared to children with more severe hearing loss, older children, and mothers with higher education levels. These studies have drawn attention to the individual differences in amplification usage among children with hearing loss, which has implications for service provision in this population.

Biographical Sketch: Walker, E.A.

a. Holte, L., Walker, E., Oleson, J., Spratford, M., Moeller, M.P., Roush, P., Ou, H. & Tomblin, J.B. (2012). Factors influencing follow-up to newborn hearing screening for infants who are hard of hearing. *American Journal of Audiology, 21,* 163-174. [PMCID: PMC3435452]
b. Walker, E. A., Holte, L., Spratford, M., Oleson, J., Welhaven, A., & Harrison, M. (2013). Timeliness of service delivery for children with later-identified mild to severe hearing loss. *American Journal of Audiology, 23,* 116-128. [PMCID: PMC3950303]
c. Walker, E.A., Spratford, M., Moeller, M.P., Oleson, J., Ou, H., Roush, P. & Jacobs, S. (2013). Predictors of hearing aid use time in children with mild-to-severe hearing loss. *Language, Speech, and Hearing Services in Schools, 44,* 73-88. [PMCID: PMC3543484]
d. Walker, E.A., McCreery, R.W., Spratford, M., Oleson, J.J., Van Buren, J., Bentler, R.A., Roush, P. & Moeller, M.P. (2015). Trends and predictors of longitudinal hearing aid use for children who are hard of hearing. *Ear and Hearing, 36,* 38S-47S. [PMCID: PMC4704121]

4. **Cumulative auditory-linguistic experience influences auditory, speech, and language outcomes in children who are hard of hearing.** These recent manuscripts have made a substantial contribution to research on children who are hard of hearing, a population that the National Institute on Deafness and Other Communication Disorders has recognized is underrepresented in the scientific literature. Our findings have helped inform theories about the extent to which audibility and consistent hearing aid use moderate the relationship between degree of hearing loss and functional outcomes.
   a. Walker E.A., Holte L., McCreery R.W., Spratford M., Page T., & Moeller M.P. (2015). The influence of hearing aid use on outcomes of children with mild hearing loss. *Journal of Speech, Language, and Hearing Research, 58*, 1611-1625. [PMCID: PMC4686313]
   b. McCreery, R.W., Walker, E.A., Spratford M., Oleson J., Bentler R., Holte L., & Roush P. (2015). Speech recognition and parent ratings from auditory development questionnaires in children who are hard of hearing. *Ear and Hearing, 36*, 60S-75S. [PMCID: PMC4703361]
   c. Ambrose, S.E., Walker, E.A., Unflat-Berry, L.M., Oleson, J.J., & Moeller, M.P. (2015). Quantity and quality of caregivers' linguistic input to 18-month and 3-year-old children who are hard of hearing. *Ear and Hearing, 36,* 48S-59S. [PMCID: PMC4703365]
   d. Walker, E.A., McCreery, R.W., Spratford, M., & Roush, P. (2016). Children with auditory neuropathy spectrum disorder fitted with hearing aids applying the American Academy of Audiology pediatric amplification guideline: Current practice and outcomes. *Journal of the American Academy of Audiology, 27,* 204-218. [PMCID: PMC4789798]

Complete List of Published Work in My Bibliography:
http://www.ncbi.nlm.nih.gov/myncbi/browse/collection/41574661/?sort=date&direction=ascending

D. Research Support (ongoing and completed research projects for the past three years).

Ongoing
Departmental Start-Up Grant Walker (PI) 07/01/15-06/30/17
University of Iowa
Research Initiation Funds
The purpose of this grant is to set up the PI's laboratory and fund preliminary studies needed to be competitive for extramural research support.
Role: PI

Clinical Research Grant Walker (PI) 12/1/16-11/30/18
American Speech-Language-Hearing Foundation
Investigating Links between Non-Linguistic Learning Processes and Grammar Skills in Children with Cochlear Implants
This project investigates whether non-verbal learning is associated with grammatical abilities in school-age children with CIs. This proposal seeks to determine whether lack of experience with sound, prior to CI receipt, leads to deficits in the development of domain-general sequential processing and learning.
Role: PI

Biographical Sketch: Walker, E.A.

1 R01 DC009560 Tomblin (PI); Moeller (PI) 08/01/13-07/31/18
NIH-NIDCD
Outcomes of School-Age Children who are Hard of Hearing
This project will obtain critical information regarding language and academic outcomes of school-age children with mild-to-severe hearing loss. The project also will provide important insight into the effectiveness of interventions concerned with mitigating hearing loss and its negative consequences. These data will form the foundation for evidence-based practice and policy for the clinical management of children with hearing loss.
Role: Co-Investigator

1 R01 DC013591 McCreery (PI) 12/01/13-11/30/18
NIH-NIDCD
Complex Listening Skills in School-Age Children who are Hard of Hearing
This project examines speech perception outcomes of school-age children with mild-to-severe hearing loss. The project also will provide important insight into the effectiveness of interventions concerned with cognitive skills and working memory.
Role: Co-Investigator

3 P50 DC00242-26A1 Gantz (PI) 02/15/12–01/31/17
NIH/NIDCD
Iowa Cochlear Implant Clinical Research Center Project VI - Developmental Studies of Children
The specific aims of this project are to examine the influence of prolonged cochlear implant experience on the speech and language development of children who receive cochlear implants.
Role: Co-Investigator in Developmental Studies Section

<u>Completed</u>
Obermann Center for Advanced Studies Interdisciplinary Research Grant 06/27/16-07/08/16
Walker (PI); Pimperton (PI)
Office of the Vice President for Research at the University of Iowa, the Avalon L. Obermann Endowment Fund, and the Laura Spelman Rockefeller Endowment Fund
The influence of age at implantation on sequential learning processes in children with cochlear implants
The purpose of this grant is to support interdisciplinary collaboration.

Role: PI5 R01 DC009560-05 Tomblin (PI); Moeller (PI) 08/01/08-07/31/13
NIH-NIDCD
Moderators and Functional Outcomes in Children with Mild to Severe Hearing Loss
This project obtained critical information regarding the extent to which mild to severe hearing loss in early childhood threatens the well-being of children. The project also provided important insight into the effectiveness of interventions concerned with mitigating hearing loss and its negative consequences.
Role: Research Associate

OMB No. 0925-0001/0002 (Rev. 08/12 Approved Through 8/31/2015)

BIOGRAPHICAL SKETCH

Provide the following information for the Senior/key personnel and other significant contributors.
Follow this format for each person. **DO NOT EXCEED FIVE PAGES.**

NAME: Jacob J. Oleson

eRA COMMONS USER NAME (credential, e.g., agency login): [redacted]

POSITION TITLE: Associate Professor

EDUCATION/TRAINING *(Begin with baccalaureate or other initial professional education, such as nursing, include postdoctoral training and residency training if applicable. Add/delete rows as necessary.)*

INSTITUTION AND LOCATION	DEGREE *(if applicable)*	Completion Date	FIELD OF STUDY
Central College	B.A.	1997	Mathematics
University of Missouri – Columbia	M.A.	1999	Statistics
University of Missouri – Columbia	Ph.D.	2002	Statistics

A. Personal Statement

As an Associate Professor in the Department of Biostatistics, College of Public Health, University of Iowa and the Director of the Center for Public Health Statistics, I conduct both biostatistical methodologic research and collaborative clinical research. Over the past decade, I have served as the lead biostatistician on numerous hearing, speech, and language related projects including, but not limited to, the cochlear implant project at the University of Iowa, Outcomes of Children with Hearing Loss, Complex Listening Skills in School-Age Hard of Hearing Children, Outcomes for School-Aged Children who are Hard of Hearing, Memory and Word Learning. In this research I work closely with all team members on study design, statistical methods, analysis, and results. This experience includes longitudinal, cohort, factor analysis, mixed models, growth curves, and missing data analyses. The collaborations also lead to methodologic work in biostatistics including a PhD dissertation on functional data analysis and growth curves which stems from longitudinal data routinely collected in hearing impairment studies. I look forward to continued collaborations with Dr. Walker on this important research.

1. Walker EA, Holte L, Spratford M, Oleson JJ, Welhaven A, Harrison M. Timeliness of Service Provision for Children with Late-identified Mild to Severe Hearing Loss. *The American Journal of Audiology*, 23, 116-128, 2014.
2. Walker EA, McCreery R, Spratford M, Oleson JJ, VanBuren J, Bentler R, Roush P, Moeller MP. Trends and predictors of longitudinal hearing aid use for children who are hard of hearing. *Ear and Hearing*, 36, 38S-47S, 2015.
3. McCreery RW, Walker EA, Spratford M, Bentler R, Holte L, Roush P, Oleson J, Van Buren J, Moeller MP. Longitudinal Predictors of Aided Speech Audibility in Infants and Chldren. *Ear and Hearing*, 36, 24S-37S.
4. Oleson JJ, Cavanaugh JE, Tomblin JB, Walker EA, Dunn CC. Combining growth curves when a longitudinal study switches measurement tools. *Statistical Methods in Medical Research*, in press (DOI: 10.1177/0962280214534588), 2014.

B. Positions and Honors

Positions and Employment

2002-2004	Assistant Professor, Dept of Math and Statistics, Arizona State University, Tempe, AZ
2004-2012	Assistant Professor, Dept of Biostatistics, University of Iowa, Iowa City, IA
2012-present	Associate Professor, Dept of Biostatistics, University of Iowa, Iowa City, IA
2014-present	Director, Center for Public Health Statistics, College of Public Health, University of Iowa
2015-present	Director of Graduate Studies, Department of Biostatistics, University of Iowa

Honors

2008	Thank a Teacher Note of Appreciation, Center for Teaching
2009	One of the Best 2008 Audiology Literature: Cochlear Implants
2012	Faculty Teaching Award, College of Public Health
2012	Top Cited Paper Impact Factor for 2011 (Hybrid 10 Clinical Trial), Audiology & Neurotology
2013	2012 ASHA Editor's Award for the American Journal of Audiology, American Speech-Language-Hearing Association
2013	Thank a Teaching Note of Appreciation, Center for Teaching
2015	Elected to Delta Omega (Public Health Honor Society)

Professional Memberships
American Statistical Association, Institute of Mathematical Statistics, International Biometric Society (ENAR), American Cochlear Implant Alliance

C. Contributions to Science

I am the lead biostatistician for the Cochlear Implant Research Center at the University of Iowa. The University of Iowa has been at the forefront of cochlear implant research for more than three decades. My role for this research center is to oversee research design, implementation, analysis, and interpretations. I work closely with all team members on the cochlear implant research studies. The sample sizes in many of these analyses are typically very small with multiple observations per subject. I use standard statistical methodology in these collaborations including t-tests, correlations, regressions, ANOVA, linear mixed models, generalized linear mixed models, and multiple imputation, as well as develop new techniques where the need arises. Modern cochlear implants preserve residual acoustic hearing during the implantation giving individuals with higher levels of pre-operative residual hearing the ability to be implanted with this remarkable device. This not only improves hearing of speech and language, but the ability to hear of music, and it leads to better cognitive processing ability as we have shown in our research.

- Gfeller K, Turner C, Oleson J, Zhang X, Gantz B, Froman R, Olszewski C. (2007) Accuracy of cochlear implant recipients on pitch perception, melody recognition, and speech reception in noise. *Ear and Hearing, 28*(3), 412-423. PMID: 17485990
- Gantz BJ, Hansen MR, Turner CW, Oleson JJ, Reiss LA, Parkinson AJ. (2009) Hybrid 10 clinical trials: Preliminary results. *Audiology and Neurotology, 14*(1), 32-38. PMID: PMC3010181
- Gfeller KG, Oleson JJ, Knutson JF, Breheny P, Driscoll V, Olszewski C. (2008) Multivariate predictors of music perception and appraisal by adult cochlear implant users. *Journal of the American Academy of Audiology, 19*(2), 120-134. PMID: PMC2677551
- Woodson EA, Dempewolf RD, Gubbels SP, Porter AT, Oleson JJ, Hansen MR, Gantz BJ. (2010) Long-term hearing preservation following microsurgical excision of vestibular Schwannoma. *Otology and Neurotology, 31*(7), 1144-1152. PMID: 20679955

I collaborate extensively with researchers in speech and language development. Again, I work closely with all research team members on study design, implementation, analysis, and reporting of results. It was recognized that research on hard of hearing children was lacking, and that a study comparing the various aspects of their development with normal hearing children and children wearing cochlear implants was needed. This work has validated the effectiveness of newborn screening and how important it is to maintain timeliness in follow-ups. The work has also shed light on hearing aid fittings, consistency of hearing aid use, accuracy of parent reports of hearing aid use, risk and resilience in speech and language, and early literacy skills. The work is leading to a "best practice" guide for clinicians and service providers around the nation.

- Spencer L, Oleson JJ. (2008) Early listening and speaking skills predict later reading proficiency in pediatric cochlear implant users. *Ear and Hearing, 29*(2), 270-280. PMID: PMC3210570
- Holte L, Walker E, Oleson JJ, Spratford M, Moeller MP, Roush P, Tomblin JB. (2012) Factors influencing follow-up to newborn hearing screening for infants who are hard-of-hearing. *American Journal of Audiology, 21*, 163-174. PMC: PMID: 22585937, PMID: PMC3435452
- Dunn CC, Walker EA, Oleson JJ, Kenworthy M, Van Voorst T, Tomblin JB, Ji H, Kirk KI, McMurray B, Hanson M, Gantz BJ. (2014) Longitudinal speech perception and language performance in pediatric cochlear implant users: The effect of age at implantation. *Ear and Hearing, 35*(2), 148-160. PMC: PMC3944377, PMID: 24231628

- Tomblin JB, Oleson JJ, Ambrose S, Walker E, Moeller M. (2014) The Influence of Hearing Aids on Speech and Language Development in Children with Hearing Loss. *Journal of the American Medical Association: Otolaryngology, 140*(5), 403-409. PMC: 24700303

My work in Bayesian spatio-temporal models has primarily been geared towards sparse data, which include excessive zero values and mission data. The conditional auto-regression (CAR) models relate similar regions on a spatial scale. I showed how the CAR model is beneficial along with an autoregressive temporal function when the data are sparse, including zero counts. We illustrated the method using turkey hunting success rates per county in Missouri (Oleson and He, 2004). Additional work integrated spatio-temporal modeling into survey statistics and small area estimation to pool strength by considering spatial priors for categorical response data with data that were not missing at random. This work was extended to survey nonresponse with a multiple wave survey approach using a multinomial response outcome when follow-up surveys are sent multiple times to those who haven't responded. Furthermore, we developed an analysis framework when the sampling design differs from the study domains. In such cases, the same areal unit contains observations from multiple strata and many of those will have zero values, so we demonstrate an appropriate way to combine the stratified estimations, which typically contain zero counts. Bayesian spatio-temporal models are naturally suited for air quality modeling. The paper Oleson, Kumar, and Smith (2013) focuses on spatio-temporal models that relate Aerosol Optical Depth (AOD) with particulate matter (PM), and determining aspects of AOD related to health and what aspects are not directly related. This involves novel spatial-temporal modeling techniques due to the high dimensionality and the large amounts of missing data.

- Oleson JJ, He CZ. (2004) Space-time modeling for the Missouri Turkey Hunting Survey. *Environmental and Ecological Statistics, 11*, 85-101.
- Oleson JJ, He CZ, Sun D, Sheriff S. (2007) Bayesian estimation in small areas when the sampling sub-domain differs from the study sub-domain. *Survey Methodology, 33*, 173-186.
- Oleson JJ, Kumar N, Smith BJ. (2013) Spatio-temporal modeling of irregularly spaced Aerosol Optical Depth data. *Environmental and Ecological Statistics, 20*(2), 297-314.
- Porter AT, Oleson JJ. (2014) A Multivariate CAR Model for Mismatched Lattices. *Spatial and Spatio-temporal Epidemiology, 11*, 79-88.

My work in infectious diseases has centered around modeling and predicting the spread of infectious diseases over both space and time. The paper by Oleson and Wikle (2013) predicted the spread of avian flu in poultry farms. The work dealt with sparse data and excessive zero counts using dimension reductions involving a two-step process of empirical orthogonal functions. In addition to this work, spatial SEIR models are promising in their ability to predict spread and control for interventions of various types. Traditional SEIR models assume a population averaged exponential decay function for the rate of change in the latent and infectious periods. In Porter and Oleson (2013), we showed how to relax the exponential decay function using a path-specific SEIR Bayesian hierarchical model that also has the ability to handle vaccinations and other intervention types. Then, Porter and Oleson (2014) extended the path specific work to include spatio-temporal structure. Brown, Oleson, and Porter (2015) created an empirically adjusted reproductive number that gives more realistic and time specific information on the reproductive number than was previously available.

- Oleson JJ, Wikle CK. (2013) Predicting Infectious Disease Outbreak Risk Via Migratory Waterfowl Vectors. *Journal of Applied Statistics, 40*(3), 656-673.
- Porter AT, Oleson JJ. (2013) A path-specific SEIR model for use with general latent and infectious distributions. *Biometrics, 69*(1), 101-108. PMC: PMC3622117, PMID: 23323602
- Porter AT, Oleson JJ. (2015) A Spatial Epidemic Model for Disease Spread Over Heterogeneous Spatial Support. *Statistics in Medicine, 35*(5), 721-733. DOI: 10.1002/sim.6730. PMID: 26365804
- Brown G, Oleson JJ, Porter AT (2015) An Empirically Adjusted Approach to Reproductive Number Estimation for Stochastic Compartmental Models: A Case Study of Two Ebola Outbreaks. *Biometrics, 72*(2), 335-343. DOI: 10.1111/biom.12432.

I am currently the Director of the Center for Public Health Statistics (CPHS) and have been involved with CPHS activities for the past 11 years. During that time, I produced the biennial Iowa Health Fact Book in 2005, 2007, and 2009 and the book has been on online only publication since 2015. This book is used by public health practitioners and professionals throughout the state of Iowa to learn more about the public health status of various health aspects for their county. This work that is conducted in partner with the Iowa Department of Public Health is just one of many important activities that CPHS engages in with IDPH.

A full listing of my published work can be found at
http://www.ncbi.nlm.nih.gov/sites/myncbi/1dSv7gT3wTr5j/bibliography/48781129/public/?sort=date&direction=ascending

D. Research Support

Ongoing Research

5 R01 DC013591 12/01/13-11/30/18
NIH-NIDCD/Father Flanagan's Boys Home
Complex Listening Skills in School-Age Children who are Hard of Hearing
PI: Ryan McCreery, Elizabeth Walker
Role: Biostatistician
The grant will help UI researchers, along with colleagues at Boys Town National Research Hospital in Nebraska and the University of North Carolina, explore whether educational and audiological services and aids can improve outcomes for young children with mild and moderate hearing disorders.

5 R01 DC009560 08/01/08-07/31/18
NIH-NIDCD
Outcomes of School-Age Children Who are Hard of Hearing
PI: Tomblin, Bruce
Role: Co-Investigator
The grant will help UI researchers, along with colleagues at Boys Town National Research Hospital in Nebraska and the University of North Carolina, explore whether educational and audiological services and aids can improve outcomes for young children with mild and moderate hearing disorders.

5 R01 DC011742 01/23/12-12/31/16
NIH-NIDCD
Memory and Word Learning
PI: McGregor, Karla
Role: Co-Investigator
The long-term goal of this research program is to develop a full explanation of the vocabulary problems associated with developmental language impairment (LI). The current objective is to examine three memory processes that support word learning: encoding, consolidation, and retrieval.

5 P50 DC000242 09/09/85-01/31/17
NIH-NIDCD
Iowa Cochlear Implant Clinical Research Center Project VI
PI: Gantz, Bruce
Role: Biostatistician
Grant funds allow researchers to continue to identify the factors that determine why some individuals benefit to a greater extent from the implant than others. In addition, researchers work to develop and evaluate new signal processing for speech perception and music appreciation and to study the expansion of selection criteria including adults with more hearing and to track the benefit of early implantation in infants.

1 R25 HL131467 02/15/16-01/31/19
NIH
Iowa Summer Institute for Research in Biostatistics
PI: Zamba, Gideon
Role: Mentor
The ultimate vision of our proposed research education program is to increase the number of undergraduates who enter graduate programs in Biostatistics and to maintain a solid underrepresented minority pipeline into biostatistics graduate programs. The proposal is for the University of Iowa (UI) Department of Biostatistics to recruit a diverse group of 18 trainees each year, from 2016 to 2018, with focus on minority, underrepresented and disadvantaged students who wouldn't have otherwise been exposed to the field of biostatistics.

No Contract #: IPA-VA Oleson MOU 04/1/14-03/31/17

DOD/Iowa City Veterans Affairs Research Foundation
Cochlear Implants
PI: Hanson, Marlan
Role: Contact PI
CDC RFA-DD14-001, Surveillance and Research of Muscular Dystrophies and Neuromuscular Disorders, Component A: Core (Existing MD Surveillance and Research Programs).

Contract #5885NB90 08/01/95-06/29/17
IDPH
IDPH FY16 Screening Data Management
PI: Oleson, Jacob (Contact PI, subcontract)
Breast and Cervical Cancer Early Detection Program, Data and Entry Analysis; WISEWOMAN Enhanced Design, Data Entry and Analysis; Data Management subcontract. Subcontract studies design, data management, and analysis on this project.

5 U01 DD001035 09/01/13-08/31/18
CDC
IOWA CBDRP: Birth Defects Study to Evaluate Pregnancy ExposureS
PI: Romitti, Paul (Contact PI)
Role: Co-Investigator

R01 TW010500-01 07/20/16-06/30/21
NIH
Epidemic Modeling Framework for Complex, Multi-Species Disease Processes and the Impact of Vertical and Vector Transmission: A Study of Leishmaniasis in Peri-Urban Brazil
PI: Oleson, Jacob J.
Despite knowledge of vertical transmission for multiple infectious diseases for at least three-quarters of a century, we do not know how vertical transmission impacts the basic reproductive number (R0) of classically vector-borne infections. With understanding gained from this study, we will be able to interpret how vertical transmission and horizontal transmission impact R0 separately, and we will quantify their interactive effect on R0.

1 R01 DC015056-01A1 08/10/16-07/31/17
Boys Town National Research Hospital
A Test of Children's English/Spanish Speech Perception in Noise or Speech Maskers
PI: Oleson, Jacob
The goal of this project is to develop, refine and evaluate a pediatric speech perception test for use with English-speaking, Spanish-speaking and bilingual children.

Completed Research
Contract #5885DW01 01/01/15-08/30/15
IDPH
IDPH Data Management Analysis
PI: Oleson, Jacob (Contact PI, subcontract)
Role: PI
Care for Yourself colorectal cancer screening program. Subcontract studies design, data management, and analysis on this project.

Contract #5885DW 02 05/09/15-10/31/15
IDPH
Health Profiles Development
PI: Oleson, Jacob (Contact PI, subcontract)
Developing a State Health Profile that includes presentation and analysis of health data and indicators identified by IDPH.

BIOGRAPHICAL SKETCH

Provide the following information for the Senior/key personnel and other significant contr butors.
Follow this format for each person. **DO NOT EXCEED FIVE PAGES.**

NAME: [redacted]

eRA COMMONS USER NAME (credential, e.g., agency login): [redacted]

POSITION TITLE: Assistant Professor, Department of Communication Sciences & Disorders, University of Iowa, Iowa City, IA

EDUCATION/TRAINING *(Begin with baccalaureate or other initial professional education, such as nursing, include postdoctoral training and residency training if applicable. Add/delete rows as necessary.)*

INSTITUTION AND LOCATION	DEGREE *(if applicable)*	Completion Date MM/YYYY	FIELD OF STUDY
National Taiwan University, Taipei, Taiwan	M.D.	05/1994	Medicine
University of Iowa, Iowa City, IA	Ph.D.	12/2007	Speech & Hearing Science
University of Iowa, Iowa City, IA	Post-doc	06/2009	Hearing Science

A. Personal Statement

I am a scientist in audiology, as well as a physician in otolaryngology. With this background I am keenly concerned about the real effect of hearing aid intervention on patients in their everyday lives. During the past five years, my research has focused on understanding how laboratory tests and retrospective self-reports such as questionnaires reflect the actual effect of hearing aids, and on identifying problems/factors that can prevent or reduce use and benefit of hearing aids for older adults. In that vein, I have teamed up with researchers in computer science to develop measurement tools that can be applied in a research setting with relevance to real-world outcomes. I also conducted several studies to investigate the best way to measure the effect of hearing aids on listening effort. The publication shown below is directly related to this project and demonstrate my qualification as a consultant.

1. [redacted] Aksan, N., Rizzo, M., Stangl, E., Zhang, X., & Bentler, R. A. (2014). Measuring listening effort: driving simulator versus simple dual-task paradigm. *Ear and Hearing, 35,* 623-632. PMCID: PMC4208979.
2. [redacted] Stangl, E., Zhang, X., Perkins, J., & Eilers, E. (in press). Psychometric functions of dual-task paradigms for measuring listening effort. *Ear and Hearing*.
3. Perreau, A. E., [redacted] Tatge, B., Irwin, D., & Corts, D. (accepted). Listening effort measured in adults with normal hearing and cochlear implants. *Journal of the American Academy of Audiology*

B. Positions and Honors

Positions and Employment

1993-1994	Internship, National Taiwan University, Taipei, Taiwan
1994-1996	Physician Officer, Taiwan Coast Guard, Taichung, Taiwan
1996-2000	Otolaryngology Resident, Department of Otolaryngology-Head and Neck Surgery, National Taiwan University, Taipei, Taiwan
2000-2001	Otolaryngologist, Department of Otolaryngology-Head and Neck Surgery, En Chu Kong Hospital, Taipei, Taiwan
2001-2003	Otolaryngologist, Department of Otolaryngology-Head and Neck Surgery, Tzu-Chi General Hospital, Chiayi, Taiwan
2003-2006	Research Assistant, Hearing Aid Laboratory, Department of Communication Sciences and Disorders, University of Iowa, Iowa City, IA.

2006-2007 Teaching Assistant, Department of Communication Sciences and Disorders, University of Iowa, Iowa City, IA.
2009-2012 Assistant Research Scientist, Department of Communication Sciences and Disorders, University of Iowa, Iowa City, IA.
2011-2012 Adjunct Assistant Professor, Department of Communication Sciences and Disorders, University of Iowa, Iowa City, IA.
2012-present Assistant Professor, Department of Communication Sciences and Disorders, University of Iowa, Iowa City, IA.

Other Experience and Professional Memberships
American Academy of Audiology, 2007-present
American Auditory Society, 2007-present
Acoustical Society of America, 2007-present
American Speech, Language & Hearing Association, 2007-present

Honors
1998 Best Resident Award, Department of Otolaryngology, National Taiwan University, Taipei, Taiwan
2006 Kenneth T. Key Scholarship, University of Iowa
2006 Student Scholarship Award, International Hearing Aids Research Conference (IHCON), Lake Tahoe, CA
2006 Student Research Grant in Audiology Award, ASHFoundation, Rockville, MD
2008 NIH Mentored Student Research Award, America Auditory Society, Scottsdale, AZ
2009 Travel Award, Aging and Speech Communication: Third International and interdisciplinary Research Conference, Indiana University, Bloomington, IN
2011 Exceptional Performance Award, University of Iowa

C. Contribution to Science

1. Hearing aid directivity assessment. My early research focused on developing and verifying electroacoustic measures to assess the directivity of directional microphone hearing aids. Knowing the directivity of a hearing aid is important because clinicians can use the information to recommend the best device and ensure that hearing aids meet reasonable and expected quality standards. The directivity measure specified in the ANSI standard, however, is unable to determine the directivity of modern directional systems because these systems interact with the acoustic environment. In my publications, I designed and validated several novel techniques that can accurately assess the directivity of modern directional systems. I have also contributed to the field by identifying the best directivity measure that can be used by clinicians to predict the effect of directional microphones on a listener's speech recognition performance.

   a. [redacted] & Bentler, R. A. (2007). Using a signal cancellation technique to assess adaptive directivity of hearing aids. *Journal of the Acoustical Society of America, 122*, 496-511.
   b. [redacted] & Bentler, R. A. (2009). Using a signal cancellation technique involving impulse response to assess directivity of hearing aids. *Journal of the Acoustical Society of America, 126,* 3214-3226.
   c. [redacted] & Bentler, R. A. (2011). A method to measure hearing aid directivity index and polar pattern in small and reverberant enclosures, *International Journal of Audiology, 50,* 405-416.
   d. [redacted], & Bentler, R. A. (2012). Clinical measures of directivity: the assumption, accuracy, and reliability. *Ear and Hearing, 33,* 44-56.

2. Ecological Momentary Assessment. A major problem in audiology research is that outcome results obtained from laboratory (e.g., speech tests) and real-world (e.g., questionnaires) measures are often not well correlated. Because one reason for this laboratory-field discrepancy is the poor sensitivity of questionnaires, I started and advocated for using the Ecological Momentary Assessment (EMA) methodology to measure real-world hearing aid outcomes. EMA is a sensitive measure, but its use in audiology is relatively rare. With this methodology, I was able to contribute to science by discovering several new factors affecting the benefit of directional microphone hearing aids in the real world, and determining the complicated relationships between age, lifestyle, and communication demand for older adults.

a. [redacted] & Bentler, R. A. (2010). Impact of visual cues on directional benefit and preference: Part 1 - laboratory tests. *Ear and Hearing, 31,* 22-34.
b. [redacted] & Bentler, R. A. (2010). Impact of visual cues on directional benefit and preference: Part 2 - field tests. *Ear and Hearing, 31,* 35-46.
c. [redacted] (2010). The effect of age on directional microphone hearing aid benefit and preference. *Journal of the American Academy of Audiology, 21,* 78-89.
d. [redacted] & Bentler, R. A. (2012). Do older adults have social lifestyles that place fewer demands on hearing? *Journal of the American Academy of Audiology, 23,* 697-711.

3. Ecological validity of laboratory tests. Another reason for the laboratory-field discrepancy regarding hearing aid outcome is that laboratory tests often do not well simulate the real world. In a series of studies I first tried to identify the real-world factors (e.g., hearing aid users' voices) that could contribute to hearing aid outcomes and should be considered in laboratory testing. These studies revealed the complicated relationships between the listener, hearing aid, and environment. I then tried to use laboratory settings that have better ecological validity to measure hearing aid outcomes. For example, our recent study ([redacted] et al 2014) used a driving simulator to measure listening effort. I have contributed to the field by recognizing the importance of using ecologically valid laboratory testing to estimate the real-world effectiveness of hearing aids and their features.

a. [redacted] & Bentler, R. A. (2012). The influence of audiovisual ceiling performance on the relationship between reverberation and directional benefit: perception and prediction. *Ear and Hearing, 33,* 604-614.
b. [redacted] Stangl, E., & Bentler, R. A. (2013). Hearing aid users' voices: A factor that could affect directional benefit. *International Journal of Audiology, 52,* 789-794.
c. [redacted] Stangl, E., Bentler, R. A., & Stanziola, R. W. (2013). The effect of hearing aid technologies on listening in an automobile. *Journal of the American Academy of Audiology, 24,* 474-485. PMCID: PMC4111914.
d. [redacted] Aksan, N., Rizzo, M., Stangl, E., Zhang, X., & Bentler, R. A. (2014). Measuring listening effort: driving simulator versus simple dual-task paradigm. *Ear and Hearing, 35,* 623-632. PMCID: PMC4208979.

4. Acceptable Noise Level (ANL). ANL is an interesting test because it has been shown to predict real-world hearing aid success. I have collaborated with researchers in Taiwan to determine the effect of language on ANL. Our works further demonstrated that ANL is predictive of hearing aid success for Taiwanese listeners, although the prediction accuracy is lower than that suggested in previous research. The research conducted in my laboratory revealed the complicated interaction between hearing aid features and ANL. Finally, I contribute to science by establishing a conceptual model for ANL. This model is developed based on empirical data and can help researchers better understand the underlying mechanism of ANL.

a. Ho, C.H., [redacted] Hsiao, S.H., Stangl, E., Lentz, E., & Bentler, R. A. (2013). The equivalence of acceptable noise level (ANL) with English, Mandarin, and non-semantic speech: A study across the U.S. and Taiwan. *International Journal of Audiology, 52,* 83-91.
b. Ho, C.H., [redacted] Hsiao, S.H., & Zhang, X. (2013). Acceptable Noise Level (ANL) and real-world hearing aid success in Taiwanese listeners. *International Journal of Audiology, 52,* 762-770.
c. [redacted] & Stangl, E. (2013). The effect of hearing aid signal processing schemes on Acceptable Noise Levels: Perception and prediction. *Ear and Hearing, 34,* 333-341.
d. [redacted] Stangl, E., Pang, C., & Zhang, X. (2014). The effect of audiovisual and binaural listening on acceptable noise level (ANL): Establishing an ANL conceptual model. *Journal of the American Academy of Audiology, 25,* 141-153.

Complete List of Published Work in MyBibliography:
http://www.ncbi.nlm.nih.gov/sites/myncbi/yu-hsiang.wu.1/bibliography/44091006/public/?sort=date&direction=descending.

D. Research Support

Ongoing Research Support
Funding source: Department of Education/NIDRR 11/2014-10/2019

Center grant: Rehabilitation Engineering Research Center on Hearing Enhancement (RERC-HE, H133E140056)
PI: Vogler, C
Title of the sub-project: Context-sensitive assessment of real-world situations via integrated smartphones and hearing aids
The purpose of the project, which is part of the RERC center grant, is to develop a system that uses the connection between smartphones and hearing aids to conduct context-sensitive assessments
Role: **PI of the sub-project** (Co-PI with Chipara, O)

Funding source: NIDCD/NIH 01/2013-12/2018
PI: Tremblay, K. and Bentler, R. A.
Title: Linking SNR to hearing aid success (R01DC012769)
The goal of this project is to investigate how brain responses to signal-to-noise ratio at the output of hearing aids and how this relationship affect hearing aid success.
Role: **Co-Investigator**

Funding source: Sivantos Inc. 01/2016-12/2017
PI: [redacted]
Title: Impact of hearing aid features on listening effort: An EEG study
The goal of this project is to investigate the effect of hearing aid features on listening effort, which is measured using EEG.
Role: **PI**

<u>Completed Research Support</u>
Funding source: NIDCD/NIH 09/2012-08/2015
PI: [redacted]
Title: Minimal technologies for hearing aid success in elderly adults (1R03DC012551)
The goal of this project is to use the Ecological Momentary Assessment to investigate real-world efficacy of hearing aid technologies in elderly adults.
Role: **PI**

Funding source: Siemens Hearing Instruments 09/2013-08/2014
PI: [redacted]
Title: Systematically investigating the effect of directional speech enhancement on listening effort
The goal of this project is to investigate the effect of new hearing aid feature on listening effort, which is the cognitive resource allocated for speech recognition using an optimized dual-task paradigm.
Role: **PI**

Funding source: ASHAFoundation 01/2014-12/2014
PI: [redacted]
Title: Measuring listening effort: Developing psychometric functions and adaptive testing procedures for the dual-task paradigm (New Century Scholar Research Grant)
The goal of this project is to systematically characterize the psychometric function of the dual-task paradigm for younger and older adults, and to examine the accuracy and reliability of a novel adaptive dual-task methodology.
Role: **PI**

Funding source: Siemens Hearing Instruments 09/2014-08/2015
PI: [redacted]
Title: Systematically investigating the effect of directional microphone on speech understanding and localization
The goal of this project is to investigate the effect of new hearing aid directional microphone technologies on speech recognition and localization in complex listening environments.
Role: **PI**

Funding source: Dalin Tzu Chi General Hospital, Taiwan 09/2013-08/2015

PI: [redacted] and Ho, H. C
Title: Acceptable Noise Levels (ANL): A trait or a state?
The goal of this project is to investigate the extent to which the ANL test taps stable (i.e., personality trait and noise sensitivity) and unstable (i.e., mood state) variance of an individual's psychological characteristic.
Role: **PI**

Funding source: Center on Aging, University of Iowa 01/2015-12/2015
PI: Chipara, O. & [redacted]
Title: Enabling cognitive load-dependent real-time assessment of hearing aid outcomes
The purpose of this project is to explore the possibility of using physiological indexes to estimate listening effort for hearing aid users in the real world.
Role: **Co-PI**

BIOGRAPHICAL SKETCH

Provide the following information for the Senior/key personnel and other significant contributors in the order listed on Form Page 2.
Follow this format for each person. **DO NOT EXCEED FOUR PAGES.**

NAME	POSITION TITLE
[redacted]	Professor
eRA COMMONS USER NAME (credential, e.g., agency login)	

EDUCATION/TRAINING *(Begin with baccalaureate or other initial professional education, such as nursing, include postdoctoral training and residency training if applicable.)*

INSTITUTION AND LOCATION	DEGREE *(if applicable)*	MM/YY	FIELD OF STUDY
University of Cambridge, Cambridge, UK	B.A.	06/81	Modern and Medieval Languages
Linkoping University, Linkoping, Sweden	M.S.	01/01	Cognitive Science
Linkoping University, Linkoping, Sweden	Ph.D.	10/05	Disability Research

A. Personal Statement.

The proposed work seeks to further understanding of the underlying mechanisms that influence listening effort in children who are hard of hearing. I have the experience and expertise to successfully serve as a consultant for this project. I have conducted research in cognitive hearing science for the past 15 years. I have received a total of ~1.5 m € as main applicant on four separate research proposals from national funding agencies in Sweden, apart from the Faculty of Arts and Sciences Research Career Contract for 2011-2013 worth ~150 000 €. As co-applicant, I have contributed to attracting a further ~11.5 m € in external funding to the research environment. This includes the Linnaeus Centre HEAD excellence grant worth ~6 m €. I have 63 peer-reviewed journal articles, and 54 publications in Web of Science with 652 citations in total and an h-index of 16. My research experience is directly relevant to the proposed work under Specific Aim 1.

B. Positions and Honors.

Professional Experience

2001-2005 Research training, Disability Research, Linkoping University, Department of Behavioral Sciences and Learning

2005-2009 Postdoctoral Research Fellow, Linkoping University, Department of Behavioral Sciences and Learning

2008 – Director of Studies of the HEAD Graduate School

2009-2013 Senior Lecturer in Disability Research, Linkoping University, Department of Behavioral Sciences and Learning

2013-2014 Associate Professor in Disability Research, Linkoping University, Department of Behavioral Sciences and Learning

2014- Professor in Disability Research, specializing in Cognitive Hearing Science, Linkoping University, Department of Behavioral Sciences and Learning

Professional activities, honors, and memberships

2015 Research consultant, National Acoustic Laboratories, Sydney, Australia (3 weeks)

2009-2015 Honorary Senior Research Associate (non-resident), University College London, UK

2011-2013 Career Research Award. Faculty of Arts & Sciences, Linköping University, ~150 000 €

2011-2013 Deputy member of Regional Ethical Review Board

2011- Cognitive Hearing Science for Communication Scientific Meeting, Linköping, Sweden; Vice Chairman of the scientific committee

2012-2014 Member of grant review board, Psychology, Swedish Research Council

2015-2019 Aging and Speech Communication, Bloomington, Indiana, USA; Member of scientific committee

Guest Associate Editor: Frontiers in Auditory Cognitive Neuroscience, Scandinavian Journal of Psychology

C. Contribution to Science.

1. A number of my publications have been directly associated with elucidating the relationship between working memory capacity and speech recognition in adverse conditions. These data support the Ease of Language Understanding model, which is designed to predict the dynamic interaction between explicit and implicit cognitive functions.
   a. [redacted] Foo, C., Sundewall-Thoren, E., Lunner, T., & Rönnberg, J. (2008). Phonological mismatch and explicit cognitive processing in a sample of 102 hearing-aid users. *International Journal of Audiology*, *47*(sup2), S91-S98.
   b. [redacted] Foo, C., Rönnberg, J., & Lunner, T. (2009). Cognition and aided speech recognition in noise: Specific role for cognitive factors following nine-week experience with adjusted compression settings in hearing aids. *Scandinavian journal of psychology*, *50*(5), 405-418.
   c. Rönnberg, J., [redacted] Foo, C., & Lunner, T. (2008). Cognition counts: A working memory system for ease of language understanding (ELU). *International Journal of Audiology*, *47*(sup2), S99-S105.
   d. Rönnberg, J., [redacted] Lunner, T., & Zekveld, A. A. (2010). When cognition kicks in: Working memory and speech understanding in noise. *Noise and Health*, *12*(49), 263.

2. My involvement in the Ease of Language Understanding model has led to further insight into the role of working memory in communication. My colleagues and I have conducted a series of studies emphasizing the neurocognitive mechanisms of working memory for sign language. This body of work describes the involvement of superior parietal regions in working memory for sign language, with reduced emphasis on temporal processing mechanisms. At the same time, these studies also show similar neurocognitive mechanisms across language modalities.
   a. [redacted] Fransson, P., Ingvar, M., Nyberg, L. & Rönnberg, J. (2007). Neural representation of binding lexical signs and words in the episodic buffer of working memory. *Neuropsychologia, 45*(10), 2258-2276.
   b. [redacted] & Rönnberg, J. (2008). Explicit processing demands reveal language modality-specific organization of working memory. *Journal of Deaf Studies and Deaf Education*, 13, 466-484.
   c. [redacted] Davidsson, L., & Rönnberg, J. (2010). Effects of age on the temporal organization of working memory in deaf signers. *Aging, Neuropsychology, and Cognition*, *17*(3), 360-383.
   d. [redacted] Karlsson, T., Gunnarsson, J. and Rönnberg, J., 2013. Levels of processing and language modality specificity in working memory. *Neuropsychologia*, *51*(4), pp.656-666.

3. In addition to the contributions described above, with a team of collaborators, I directly documented the relation between cognitive abilities, speech perception, and brain activity using neuroimaging techniques, specifically fMRI. The purpose of this research is to increase our understanding of the neural correlates of language, and the role of auditory deprivation on cross-modal plasticity. This body of work describes 1) left lateralized networks for evaluating semantic context, 2) plastic reorganization of cortical regions of the brain in deaf individuals; and 3) crossmodal plasticity in individuals who have experienced auditory deprivation.
   a. Zekveld, A.A., [redacted] Johnsrude, I.S., Heslenfeld, D., Rönnberg, J. (2012). Behavioural and fMRI evidence that cognitive ability modulates the effect of semantic context on speech intelligibility. *Brain & Language, 122*(2), 103-113.
   b. Cardin, V., Orfanidou, E., Rönnberg, J., Capek, C.M., [redacted] & Woll, B. (2013). Dissociating cognitive and sensory neural plasticity in human superior temporal cortex. *Nature Communications, 4*, 1473.
   c. Cardin, V.*, Smittenaar, C.F., Orfanidou, E., Rönnberg, J., Capek, C.M., [redacted] & Woll, B. (2015). Differential activity in Heschl's gyrus between deaf and hearing individuals is due to auditory deprivation rather than language modality. *NeuroImage, 124*, 96-106.

4. My recent research has sought to determine factors that influence semantic knowledge and working memory performance in adults. In particular, we have examined the effect of hearing loss on verbal reasoning in adults. My colleagues and I have shown that hearing aid usage may serve as a protective factor in verbal reasoning performance for individuals who experience difficulty listening in noise. These

data are consistent with previous results suggesting that hearing aid use may slow the decline in cognitive skills for adults with hearing loss.

a. Zekveld, A. A., [redacted] Johnsrude, I. S., Festen, J. M., Van Beek, J. H., & Rönnberg, J. (2011). The influence of semantically related and unrelated text cues on the intelligibility of sentences in noise. *Ear and hearing*, *32*(6), e16-e25.
b. Keidser, G., [redacted] Hygge, S. & Rönnberg, J. (2016). The effect of functional hearing and hearing aid usage on verbal reasoning in a large community-dwelling population. *Ear and Hearing, 37*(1), 26-36.
c. [redacted] Orfanidou, E., Cardin, V., Capek, C.M., Woll, B & Rönnberg, J. (2016). Pre-existing semantic representation improves working memory performance in the visuospatial domain. *Memory & Cognition*, Early online.
d. [redacted] Mishra, S., Stenfelt, S., Lunner, T & Rönnberg, J. (2016). Seeing the talker's face improves free recall of speech for young adults with normal hearing but not older adults with hearing loss. *Journal of Speech, Language, and Hearing Research*, in press.

D. Research Support (ongoing and completed research projects for the past three years).

Ongoing

Swedish Research Council 2016-2020
Generalizing the disuse hypothesis
This project is a longitudinal study of memory in deaf signers.
Role: PI

Swedish Research Council 2016-2019
The Janus face of auditory distraction
This project examines attention and working memory mechanisms in persons with ADHD.
Role: co-investigor

Swedish Research Council for Health, Working Life, and Welfare 2016-2018
The sensory cognitive communication factor: preserving social interaction and health in aging
This project investigates social interaction and aging in adults with hearing impairment.
Role: co-investigator

PHS 398 Cover Page Supplement

OMB Number: 0925-0001

Expiration Date: 10/31/2018

1. Human Subjects Section

Clinical Trial? ❍ Yes ● No

*Agency-Defined Phase III Clinical Trial? ❍ Yes ❍ No

2. Vertebrate Animals Section

Are vertebrate animals euthanized? ❍ Yes ❍ No

If "Yes" to euthanasia

Is the method consistent with American Veterinary Medical Association (AVMA) guidelines?

❍ Yes ❍ No

If "No" to AVMA guidelines, describe method and proved scientific justification

3. *Program Income Section

*Is program income anticipated during the periods for which the grant support is requested?

❍ Yes ● No

If you checked "yes" above (indicating that program income is anticipated), then use the format below to reflect the amount and source(s). Otherwise, leave this section blank.

*Budget Period	*Anticipated Amount ($)	*Source(s)

PHS 398 Cover Page Supplement

4. Human Embryonic Stem Cells Section

*Does the proposed project involve human embryonic stem cells? ❍ Yes ● No

If the proposed project involves human embryonic stem cells, list below the registration number of the specific cell line(s) from the following list: http://grants.nih.gov/stem_cells/registry/current.htm. Or, if a specific stem cell line cannot be referenced at this time, please check the box indicating that one from the registry will be used:

Specific stem cell line cannot be referenced at this time. One from the registry will be used.

Cell Line(s) (Example: 0004):

5. Inventions and Patents Section (RENEWAL)

*Inventions and Patents: ❍ Yes ● No

If the answer is "Yes" then please answer the following:

*Previously Reported: ❍ Yes ❍ No

6. Change of Investigator / Change of Institution Section

❏ Change of Project Director / Principal Investigator

Name of former Project Director / Principal Investigator

Prefix:

*First Name:

Middle Name:

*Last Name:

Suffix:

❏ Change of Grantee Institution

*Name of former institution:

PHS 398 Modular Budget

OMB Number: 0925-0001
Expiration Date: 10/31/2018

Budget Period: 1

Start Date: 07/01/2017 End Date: 06/30/2018

A. Direct Costs

	Funds Requested ($)
Direct Cost less Consortium Indirect (F&A)*	[redacted]
Consortium Indirect (F&A)	[redacted]
Total Direct Costs*	[redacted]

B. Indirect (F&A) Costs

	Indirect (F&A) Type	Indirect (F&A) Rate (%)	Indirect (F&A) Base ($)	Funds Requested ($)
1.	on_campus	[redacted]	[redacted]	[redacted]
2.				
3.				
4.				

Cognizant Agency
(Agency Name, POC Name and Phone Number) DHHS, Theodore Foster, [redacted]

Indirect (F&A) Rate Agreement Date 02/09/2015

Total Indirect (F&A) Costs [redacted]

C. Total Direct and Indirect (F&A) Costs (A + B)

Funds Requested ($) [redacted]

PHS 398 Modular Budget

Budget Period: 2
Start Date: 07/01/2018   End Date: 06/30/2019

A. Direct Costs

	Funds Requested ($)
Direct Cost less Consortium Indirect (F&A)*	[redacted]
Consortium Indirect (F&A)	[redacted]
Total Direct Costs*	[redacted]

B. Indirect (F&A) Costs

	Indirect (F&A) Type	Indirect (F&A) Rate (%)	Indirect (F&A) Base ($)	Funds Requested ($)
1.	on_campus	[redacted]	[redacted]	[redacted]
2.				
3.				
4.				

Cognizant Agency (Agency Name, POC Name and Phone Number): DHHS, Theodore Foster, [redacted]

Indirect (F&A) Rate Agreement Date: 02/09/2015

Total Indirect (F&A) Costs: [redacted]

C. Total Direct and Indirect (F&A) Costs (A + B)

Funds Requested ($): [redacted]

PHS 398 Modular Budget

Budget Period: 3	
Start Date: 07/01/2019	End Date: 06/30/2020

A. Direct Costs

	Funds Requested ($)
Direct Cost less Consortium Indirect (F&A)*	[redacted]
Consortium Indirect (F&A)	[redacted]
Total Direct Costs*	[redacted]

B. Indirect (F&A) Costs

	Indirect (F&A) Type	Indirect (F&A) Rate (%)	Indirect (F&A) Base ($)	Funds Requested ($)
1.	on_campus	[redacted]	[redacted]	[redacted]
2.				
3.				
4.				

Cognizant Agency
(Agency Name, POC Name and Phone Number) DHHS, Theodore Foster, [redacted]

Indirect (F&A) Rate Agreement Date 02/09/2015

Total Indirect (F&A) Costs [redacted]

C. Total Direct and Indirect (F&A) Costs (A + B)

Funds Requested ($) [redacted]

PHS 398 Modular Budget

Cumulative Budget Information	
1. Total Costs, Entire Project Period	
Section A, Total Direct Cost less Consortium Indirect (F&A) for Entire Project Period($)	[redacted]
Section A, Total Consortium Indirect (F&A) for Entire Project Period ($)	
Section A, Total Direct Costs for Entire Project Period ($)	
Section B, Total Indirect (F&A) Costs for Entire Project Period($)	
Section C, Total Direct and Indirect (F&A) Costs (A+B) for Entire Project Period($)	
2. Budget Justifications	
Personnel Justification	PERSONNEL_JUSTIFICATION1029558688.pdf
Consortium Justification	
Additional Narrative Justification	

Tracking Number: GRANT12275876

Funding Opportunity Number: PAR-16-057. Received Date: 2016-10-24T10:25 42 000-04:00

PERSONNEL JUSTIFICATION

Senior/Key Persons:

Elizabeth A. Walker, Ph.D., Principal Investigator (effort = 2.7 AY). Dr. Walker is the Director of the Pediatric Audiology Laboratory and Assistant Professor at the University of Iowa. Dr. Walker will be responsible for the overall administration of the project. Specific responsibilities include experimental design, data collection and analyses, overall management and prioritizing of specific experiments, interpretation of data, manuscript preparation, and budget management.

Jacob Oleson, Ph.D. Statistician (effort = 0.48 CY months). Dr. Oleson is an Associate Professor in Biostatistics and a faculty member in the Center for Public Statistics for the College of Public Hearing at the University of Iowa. He has served as lead biostatistician on the UI Cochlear Implant project for the past 8 years and the Outcomes of Children with Hearing Loss Study for the past 6.5 years. In addition, Dr. Oleson is a statistical consultant for the Journal of Speech, Language, Hearing Research. Dr. Oleson and Dr. Walker have a long-standing collaboration, and Dr. Oleson will provide support in study design, statistical methods, analysis, and results.

Other Significant Contributors:

[redacted] **Ph.D., In-kind consultant (effort = zero person months).** [redacted] is the Director of the Hearing and Aging Laboratory and Assistant Professor at the University of Iowa. [redacted] area of expertise involves real-world outcome measures of hearing devices. He will be a consultant for aspects of the project related to dual-task paradigms.

[redacted] **Ph.D., consultant (effort = zero person months).** [redacted] is an Assistant Professor at the Swedish Institute for Disability Research in Linkoping, Sweden. She is also the Director of Studies at the HEAD Graduate School and Deputy Research Manager at Linneaus Centre HEAD. [redacted] area of research expertise is in cognitive and neural organization of language memory, with specific emphasis on the neurocognitive organization of language with and without the mediation of hearing aids. [redacted] will be a consultant for aspects pertaining to language and working memory as contributors to listening effort in Aim 1.

Other Personnel:

TBR, Post-doctoral research fellow (effort = 12 CY months). The post-doctoral research fellow will be trained in all grant procedures. S/he will be primarily responsible for data collection for hearing-related, standardized cognitive and language assessments, and experimental tasks. Additional responsibilities will include oversight of data entry and storage, subject consent, scheduling, and payments, preparation of testing materials. The fellow will also collaborate on manuscripts and data dissemination.

PHS 398 Research Plan

OMB Number: 0925-0001
Expiration Date: 10/31/2018

Introduction	
1. Introduction to Application (Resubmission and Revision)	LE_Introduction1030133181.pdf
Research Plan Section	
2. Specific Aims	LE_Specific_Aims1030133133.pdf
3. Research Strategy*	LE_Research_Strategy1030133135.pdf
4. Progress Report Publication List	
Human Subjects Section	
5. Protection of Human Subjects	ProtectionHumanSubjects_LE1029365375.pdf
6. Data Safety Monitoring Plan	
7. Inclusion of Women and Minorities	INCLLUSION_OF_WOMEN_AND_MINORITIES1029105135.pdf
8. Inclusion of Children	INCLUSION_OF_CHILDREN1029105136.pdf
Other Research Plan Section	
9. Vertebrate Animals	
10. Select Agent Research	
11. Multiple PD/PI Leadership Plan	
12. Consortium/Contractual Arrangements	
13. Letters of Support	LE_Letters_of_Support1030133274.pdf
14. Resource Sharing Plan(s)	Data_Sharing_Plan_LE1029365379.pdf
15. Authentication of Key Biological and/or Chemical Resources	
Appendix	
16. Appendix	

INTRODUCTION (RESUBMISSION)

I am grateful for the reviewers' thorough feedback of the original proposal. The reviewers recognized the uniqueness of this proposal, acknowledging that children who are hard of hearing (CHH) are an understudied population and that "the proposed research is strongly hypothesis driven and the goals are significant." Each reviewer raised important concerns. I have addressed these concerns and the application is now stronger. Changes are marked by a bold line on the right margin.

Lack of detail. All reviewers requested more information about the experimental procedure. The following methodological details were added to the Stimuli and Procedures section based on reviewer comments:

- Added detail about scoring the primary task as percent-correct words (Reviewer 3). I have also incorporated Reviewer 3's suggestion to assess the influence of predictor variables (aided audibility, working memory, vocabulary) on sentence repetition as a secondary goal of Aim 1.
- Added detail about the secondary task (Reviewer 1). The secondary task has been successfully used by my consultant, [redacted] et al., in press). While the secondary task in the current proposal is a simple visual reaction time task, it can be adapted into a visual Stroop task, thus increasing the processing load of the secondary task. This gives me the advantage of collecting data on performance with a simple visual response time task in the current grant cycle, with the opportunity to modify the experiment to examine the effect of varying the processing load on the secondary task in future studies. The proposed visual reaction time secondary task in the current study will also allow me to reduce the "task bias" that has occurred in previous studies on listening effort in children, in which children allocated more attention to the secondary task, perhaps because it was more interesting than the primary task. Information about outliers and false alarms/misses have also been added.
- Modified subjective ratings (Reviewer 1). I have revised the subjective rating scale to involve a 10 point scale instead of a 100 point scale. The proposal also includes training on the subjective ratings, to encourage participants to utilize the entire scale. The training consists of having children judge effort on a physical task, a mathematics task, and a reading task, with three levels of difficulty embedded into each practice item. While this may not eliminate the possibility that children are interpreting the question differently, as the reviewer mentions, it does reduce that possibility by providing multiple exemplars prior to the experiment. Pilot data indicate these modifications were successful (Aim 1: Preliminary data).

Lack of pilot data (Reviewer 1). I have collected pilot data on 7 CHH (3 CHH in Aim 1 and 4 other CHH in Aim 2). Based on these pilot data, I have modified the procedures to improve the feasibility of the proposal (Aims 1 and 2: Preliminary Data). One major modification from the original proposal is the SNR presentation levels have been changed to -2, +2, and +6 dB SNR. Pilot CHH had an average speech recognition score of 19% at -5 dB (range = 12-24%), suggesting this condition is too difficult for CHH. The average score at 0 dB was 51% (range = 43-58%), indicating -2 dB SNR will not result in floor performance.

Justification of the dual-task paradigm (Reviewer 3). The primary goal of this study is to identify the factors that influence listening effort in CHH. Dual-task procedures are an accepted means for objectively quantifying listening effort (Gosselin & Gagne, 2011) and are an effective way of measuring the role of hearing aids on listening effort (Downs, 1982; Hornsby, 2013). At the same time, I appreciate the reviewer's hesitation about the dual-task paradigm, which is why I have also included subjective rating scales and measures of verbal reaction time on the primary task as additional measures of listening effort. Subjective ratings are sensitive to differences in SNR ([redacted] et al., 2012). Verbal response times are a valid third option for measuring listening effort, and have been used previously in studies with children (Gustafson et al., 2014). The proposal looks at several different means of measuring listening effort, which will provide insight into the most reliable and valid techniques for assessing listening effort in children, a topic that has not been thoroughly evaluated in the listening effort literature.

Number of lead-author publications (Reviewer 2). I have updated my Biosketch to address this concern. I am currently in my second year as an assistant professor. I am first author on 8 manuscripts (and one recently accepted). I am second author on 8 additional manuscripts. I have two manuscripts that are currently in revision. Since completing my dissertation, I have averaged four publications a year. I have also received two Editors' awards for peer-reviewed articles of highest merit.

Alter the practice arrangement to be at an SII of 1.0 (Reviewer 2). The SII is a participant-specific variable related to individual audiometric thresholds. In the case of aided SII, SII is also related to the proximity of the aided response of the hearing aids to prescriptive targets. As a result, CHH with high pure-tone thresholds and/or poorly-fit hearing aids cannot achieve an SII of 1.0 even under optimal listening conditions. I appreciate that the reviewer understands the importance of emphasizing SII over pure-tone average, but it is not feasible to alter practice arrangements in this fashion.

Anticipate that training to improve vocabulary will improve language use (Reviewer 2). This is an interesting question that has not been addressed in previous studies with CHH. I will evaluate it in the current proposal by looking at the association between vocabulary size and listening effort.

SPECIFIC AIMS

Hearing loss affects nearly 15% of school-age children (Niskar et al., 1998). Children who are hard of hearing (CHH) regularly experience communication challenges due to limited auditory access. These challenges are further compounded because CHH are particularly vulnerable to the effects of poor acoustics during listening tasks (Finitzo-Hieber & Tillman, 1978) and academic listening environments are characterized by poor signal-to-noise ratios (Crandell & Smaldino, 2000). In adverse listening conditions, CHH expend increased **listening effort** compared to children with normal hearing (CNH; Hicks & Tharpe, 2002). Listening effort is defined as the allocation of mental resources to overcome obstacles in goal pursuit during listening tasks (Pichora-Fuller et al., 2016). To date, research in the pediatric literature has focused primarily on the role of unaided hearing to explain differences in listening effort between CHH and CNH, and within CHH. However, research has also shown that inconsistent auditory access in early childhood constrains the development of higher-level, cognitive-linguistic skills (Tomblin et al., 2015). Cognitive-linguistic skills have been shown to impact listening effort in adults with hearing loss (Ng et al., 2013). Evidence suggests that both hearing loss and cognitive-linguistic skills result in increased listening effort, but the interplay of these factors has not been thoroughly investigated. This knowledge gap hinders our understanding of the underlying mechanisms that drive individual differences in listening effort in CHH, which limits our ability to develop evidence-based interventions for this population. <u>The current proposal seeks to determine how hearing loss and cognition interact to influence listening effort in school-age CHH.</u>

The long-term goals for this research program are 1) to identify malleable and non-malleable factors that impact listening and learning in school-age CHH, and 2) to develop evidence-based interventions that focus on malleable factors. The primary objective of the current proposal addresses these long-term goals by characterizing the relations between auditory access, cognitive and linguistic skills, and listening effort in CHH. The central theory guiding the proposed work is that listeners require additional cognitive resources to maintain optimal performance during adverse listening conditions, and this demand on resources results in a decline in performance on secondary tasks. Specifically, I hypothesize that top-down processing, measured by **working memory** and **linguistic skills**, is associated with listening effort in school-age CHH, and this relationship is moderated by access to the acoustic-phonetic details in the signal, reflected by **aided audibility**. CHH with stronger working memory and linguistic skills will show reduced listening effort (i.e., faster reaction times in dual-task paradigms and subjective reports of experiencing less effort), compared to CHH with more limited abilities. Higher-level cognitive skills, such as working memory capacity, have been shown to influence listening effort in adults with hearing loss, but these factors have not been directly studied in children. By measuring auditory access, cognitive-linguistic variables, and listening effort in CHH, this project will examine the factors that support listening and multitasking in adverse conditions.

Specific Aim 1: To determine the effect of higher-level cognitive-linguistic skills on listening effort in school-age children who are hard of hearing, and to evaluate the extent to which auditory access influences the relationship between cognitive-linguistic skills and listening effort. In pursuing this aim, I will test the hypothesis that stronger working memory and vocabulary skills are associated with lower amounts of listening effort (i.e., faster reaction times in the secondary task of a dual-task paradigm and lower subjective ratings of listening effort during sentence repetition) in CHH. Furthermore, I expect the relationship between cognition and listening effort to be stronger for CHH who have poorer aided audibility because they must rely more on cognitive-linguistic skills to compensate for their reduced access to sound.

Specific Aim 2: To identify the effects of hearing aid use and background noise on listening effort in children who are hard of hearing. CHH vary in their amount of daily hearing aid (HA) use. Furthermore, there is ambiguity regarding appropriate clinical management for some CHH (i.e., children with milder loss). The hypothesis for this aim is that HA use will provide increased access to speech cues, which will reduce the cognitive load involved in listening, even for those children with milder loss. Based on this hypothesis, I predict that 1) HAs will reduce listening effort for CHH, compared to listening without HAs; 2) listening in quiet will result in decreased listening effort relative to listening in noise. This aim extends my prior work regarding variations in consistency of daily HA use for some CHH. The data will provide support for encouraging consistent device use for CHH and optimizing acoustic conditions in the classroom, both for CHH and CNH.

Impact. Data from this proposed study will generate new knowledge regarding the influence of auditory access and cognitive-linguistic skills on listening effort in school-age children. These findings have the potential to provide insight into the ways in which we can help CHH cope with classroom listening demands.

RESEARCH STRATEGY

A. Significance

Scientific Premise. Hearing loss (HL) in childhood is a relatively common condition, experienced by 15% of children (Niskar et al., 1998). Children who are hard of hearing (CHH) are now being identified and fit with hearing aids (HAs) during infancy (Holte et al., 2012). These service provisions are posited to have a positive, long-term impact on functional outcomes. Nevertheless, CHH are still at risk for language delays (Tomblin et al., 2015). Until recently there were few studies that focused exclusively on children with bilateral, mild-to-severe HL. We know that consistent access to sound is critical for CHH to achieve age-appropriate language skills, which are essential for academic achievement. Historically, however, we have lacked information on factors that are amenable to intervention (i.e., malleable factors), such as amount of access to the speech spectrum via HAs (McCreery et al., 2015) or amount of daily HA use (Walker et al., 2015). Furthermore, an NIDCD working group identified a research priority related to managing listening demands in complex listening environments in CHH (Eisenberg et al., 2007), which requires investigators to go beyond examining performance on traditional clinical measures (e.g., speech recognition). Although speech recognition tests are clinically useful, they are not sensitive to the cognitive demands of real-world listening, which requires multitasking and reliance on cognitive-linguistic skills. This is particularly true in school, where a student is expected not only to listen to a teacher's message in a degraded listening environment, but also to fully comprehend and integrate that message, while simultaneously performing other tasks (e.g., taking notes). For CHH, there is evidence that multitasking situations are taxing due to the additional listening effort needed to understand speech (Hicks & Tharpe, 2002). However, we are limited in our understanding of the factors that are associated with listening effort. To identify these factors, we must utilize measures that are sensitive to both bottom-up and top-down processes required for recognizing speech. The dual-task paradigm is a quantitative objective measure to assess listening effort (Sarampalis et al., 2009). In this paradigm, an individual performs two tasks simultaneously. As the primary task increases in difficulty, decrements on the secondary task reflect increased effort. Subjective ratings of perceived listening effort are another approach that may be used in conjunction with objective measures (Gosselin & Gagne, 2011[redacted]et al., 2012). CHH demonstrate individual differences in listening effort on both of these measures (Hicks & Tharpe, 2002). There is strong empirical support that cognitive skills in adults are associated with individual differences in listening effort (Desjardins & Doherty, 2014). Because CHH have limited access to the acoustic signal, it is plausible that better cognitive-linguistic skills will compensate for decreased audibility with this group, as it does with adults. Thus, I hypothesize that auditory access and cognitive-linguistic skills contribute to individual differences in listening effort for CHH. The effects of auditory access, memory, and language on listening effort in CHH have not been widely studied. In summary, there are gaps in our knowledge regarding factors that drive increased listening effort in CHH. It is critical to fill these gaps because mounting evidence suggests that listening effort puts CHH at high risk for fatigue (Bess et al., 2016), and fatigue is associated with decreased language skills in children with HL (Werfel & Hendricks, 2016).

The current proposal fills our knowledge gap directly by using behavioral and subjective measures of listening effort. According to Capacity Theories of Attention (Broadbent, 1958; Kahneman, 1973), the brain has a fixed capacity for attention. Dual-task paradigms are based on this theory: if a listener directs more attention towards the primary, auditory task when the signal is degraded, more resources are directed to the bottom-up process of attending to the acoustic-phonetic input. Thus, there is a reduction in resources for top-down, cognitive-linguistic processes, and performance on the secondary task declines. Previous studies have shown mixed results using dual-task paradigms with children. Hicks and Tharpe (2002) demonstrated a main effect on the secondary task for hearing status (normal hearing vs hard of hearing), but not for noise level. However, their noise conditions ranged from +10 to +20 dB signal-to-noise ratio (SNR), which were likely not difficult enough to elicit an effect of SNR on listening effort. McFadden and Pittman (2008) did not find an effect for hearing status or noise level, but they only included 10 children with mild or unilateral HL and utilized a secondary task (i.e., dot-to-dot task) that may have been more engaging than the primary task, resulting in task bias. In contrast, Howard et al. (2010) did find an effect of poorer SNR on listening effort in a dual-task paradigm in 9-12 year old children with normal hearing (CNH), using SNRs ranging from -4 to +4 dB, but did not include CHH. The current proposal rectifies some of the previous issues with dual-task paradigms in CHH and CNH, by utilizing a simple visual reaction time task to reduce task bias, and listening conditions that are sensitive to differences in listening effort and representative of classroom listening environments (Arnold & Canning, 1999). The current proposal also captures additional aspects of listening effort via subjective ratings, which are valuable for measuring individuals' self-perception of listening effort.

Significance of the Expected Research Contribution. This proposal seeks to determine the impact of auditory access and cognitive-linguistic skills on listening effort. This proposed research is scientifically significant, because it will advance our knowledge of the underlying mechanisms that comprise listening effort. It will inform theoretical models regarding the integration of low-level, acoustic-phonetic input and higher-level, cognitive-linguistic processes involved in listening, using a mechanistic approach to examine listening effort. Identifying the potential effects of these underlying mechanisms will have translational significance: this knowledge will lead to an understanding of which specific factors to target in intervention (e.g., vocabulary and working memory skills) in order to help CHH develop supportive skills that will allow them to withstand the demands of adverse conditions on listening effort. This knowledge is also highly relevant to exploring how provision of well-fit, consistently worn HAs (i.e., malleable factors) may protect CHH from increased listening effort.

B. Innovation

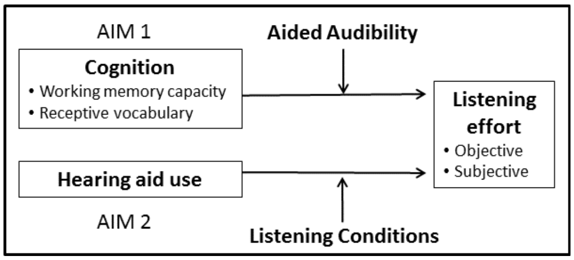

Fig. 1. ***Theoretical model of factors influencing listening effort***

The framework and approach in this proposal represent a substantial departure from previous investigations. Although listening effort models have been developed for adults, this proposal is one of the first to apply a theoretical model (**Fig 1**) that integrates measures of auditory access and cognitive-linguistic skills as concurrent predictors of listening effort in CHH. Previous studies with adults indicate that cognitive skills are related to the ability to manage listening demands in degraded acoustic environments (Ng et al., 2013), but the underlying mechanisms driving listening effort in CHH remain undetermined. In addition, the current proposal incorporates an innovative method to characterize the auditory access of CHH. Past studies used pure tone average (PTA) to predict individual differences in listening effort (Hicks & Tharpe, 2002). PTA is a means for describing degree of HL; it is calculated by taking the average of unaided hearing thresholds for pure-tone stimuli at 3 or 4 frequencies. Rather than describing access to sound in terms of unaided thresholds to pure-tone stimuli, I will use aided audibility, quantified by the Speech Intelligibility Index (SII). Aided SII is a means for describing the percentage of speech that is accessible with HAs at a given input level. It more accurately represents the everyday listening experiences of CHH than unaided PTA. It can be used to account for amplification characteristics of HAs, including proximity of HA fit to prescriptive targets (McCreery et al., 2015), variability in ear canal acoustics, and amount of access to the speech spectrum at a conversational level (Stiles et al., 2012). Studies have yet to explore the impact of aided SII on listening effort. Confirmation or rejection of the proposed model will inform theories of listening effort by providing in-depth exploration of the perceptual and cognitive mechanisms that underlie effortful listening. The proposed study is also innovative in that it examines the utility of behavioral and subjective tools. This will lay the groundwork for a future R01 that explores the use of physiological techniques (e.g., fMRI and EEG) to measure listening effort.

C. Approach

General methods: Methods and details common to all aims are summarized below.

Participants: Participants will be 8-12 year old CHH and CNH. Inclusion criteria for CHH are better-ear 4-frequency PTAs between 20 and 75 dB HL. Children with cochlear implants, unilateral HL, or those who use sign language will be excluded. CNH will have PTA no greater than 20 dB HL. Exclusion criteria for CHH and CNH include a primary language other than English and diagnoses of neurodevelopmental disorders. All children will receive the Goldman-Fristoe Test of Articulation-2 (Goldman & Fristoe, 2000) to identify consistent phonological error patterns, which will be taken into account during speech recognition testing. Children with nonverbal IQ of 1 SD or more below the normative mean, as measured by the Wechsler Abbreviated Scale Intelligence (Wechsler & Hsiao-pin, 2011) Block Design and Matrix Reasoning subtests, will be excluded.

CHH will be recruited via an existing cohort from the Outcomes of Children with Hearing Loss study (OCHL; R01 DC009560) and new CHH identified by audiologists (see Letters of Support). The median age at HA fitting for CHH in OCHL is 6 months (mean = 19; SD = 20). Mean daily HA use for CHH who participated in OCHL was 10 hrs/day, but daily HA use varies widely in CHH (Walker et al., 2015), ranging from 0 to 24 hrs/day.

Stimuli and procedures: The speech stimuli will be delivered via custom programming on the experimenter's computer. The auditory output will be routed from an audiometer to loudspeakers.

Dual-task experiments. In Aims 1 and 2, the *primary task* involves repeating back sentences, using sentence stimuli from the Hearing in Noise Test (HINT; Soli & Wong, 2008), appropriate for children 8 to 12 years old (Anderson et al., 2005). The HINT consists of one male talker with speech-shaped noise as the masker, with 24 lists and 10 sentences per list (no repetitions during testing). The *secondary task* is a simple visual reaction time task (Wu et al., in press), presented and measured through E-Prime. Participants push the space bar in response to seeing a word (red, blue, yellow, green, randomly presented) appear on a computer screen. The participants do not need to perform any action other than pushing the space bar when the word appears. One visual stimulus item is presented with one HINT sentence per trial (visual stimuli are presented randomly during the second half of each HINT sentence, to maximize processing load). Conditions vary in difficulty based on the SNR. For each condition, two HINT lists are presented. Participants respond to 20 sentences and 20 visual stimuli per trial. Reaction time is the time between stimulus word onset and the space bar being pushed. For each participant we will calculate the median of the 20 reaction times in a condition. This median score serves as the reaction time for each SNR condition. Medians instead of means will be used to control for outliers. Outliers will also be dealt with by removing reaction time values that are below or above boundaries set by 1.5 times the inter-quartile range from the analysis (Hicks & Tharpe, 2002). False alarms and misses will be recorded and removed from the dataset.

Subjective ratings. Participants will rate their perceived effort on a 10-point scale. Participants will rate the primary task ("How much effort did you put into repeating the sentences?") and the secondary task ("How much effort did you put into pushing the space bar?") by responding verbally and marking it on visual analog scale. The experimenter will ask the questions while the participants read the questions and look at the scale. Pre-test training on the subjective ratings will include three practice items that encourage utilization of the entire scale.

Audiometry. For CHH, air-conduction thresholds at octaves from .25–8 kHz and bone-conduction thresholds from .5–4 kHz will be measured. Thresholds will be used to calculate aided SII. CNH will be screened at 20 dB HL.

HA Data. For CHH, examiners will measure electroacoustic HA characteristics to determine aided SII at a conversational level of 65 dB SPL input (ANSI S3.5-1997 R2007).

Study Design and Power Analyses. The general analytic approach will be multiple regression organized within a path-analytic framework where variables serve as predictors, moderators of predictors, or outcomes. The primary analyses will be multiple regression and ANOVA. In Aim 1, with 60 6th grade CHH, there is 80% power to detect standardized regression coefficients of .40 or greater at a 5% level of significance. Aims 1 and 2 also use ANOVA. For Aim 1, there is 80% power to detect an effect size of .37 for 30 CNH and 30 CHH at a 5% level of significance. After correcting for family-wise error rate (α = .0125), there is power to detect an effect size of .44. For Aim 2, there is 80% power to detect an effect size of .50 for 30 CHH at a 5% level. Linear mixed models (LMM) will also be done as validation of the primary analyses, because of methodological concerns associated with reaction time analysis (i.e., heavily skewed data). Furthermore, LMM are more statistically powerful than ANOVA and more flexible in handling missing data and dropout.

Scientific Rigor and Reproducibility. Analyses and data sharing will adhere to the NIH's mission of funding rigorous science. This will be accomplished through the analytic approach described above, which replicates the approach used in prior studies of listening effort. Relevant biological variables (e.g., sex) will be considered in analyses and dissemination. To achieve transparency, details will be reported that allow others to reproduce the results and data will be made available to other researchers via a data enclave (see Data Sharing Plan).

Aim 1. To determine the effect of higher-level cognitive-linguistic skills on listening effort in school-age children who are hard of hearing, and to evaluate the extent to which auditory access influences the relationship between cognitive-linguistic skills and listening effort.

Introduction. Underlying mechanisms that are associated with effortful listening in children are not well understood. The *objective of the current aim* is to identify whether auditory, linguistic, and memory factors underlie increased listening effort in CHH. To attain this objective, I will test the *working hypothesis* that poorer working memory and vocabulary skills will be associated with greater amounts of listening effort in CHH, and this relationship will be moderated by auditory access. I predict that the relationship between cognitive-linguistic skills and listening effort will be stronger for children who have poorer aided audibility, because they must rely more on explicit cognitive-linguistic skills to compensate for their reduced access to sound. These hypotheses will be tested through the *approach* of using aided SII, vocabulary, and working memory as predictors. I will collect objective (reaction time) and subjective (self-report ratings) data as outcome measures. The *rationales* for this aim are that successful completion of this research will fill important gaps in our knowledge of 1) the factors that account for individual differences in listening effort in CHH and 2) why CHH expend additional effort in listening, compared to CNH. The data obtained in Aim 1 are a critical first step towards achieving my long-term goal of developing evidence-based strategies that will aid in identification and intervention of CHH who are at risk for difficulties in academic settings. The inclusion of aided SII allows me to examine how malleable factors influence listening effort, as research shows that aided SII in CHH varies as a function of the quality of HA fittings (McCreery et al., 2015).

Justification and feasibility. Only one prior study has explored factors related to individual differences in listening effort in CHH. Hicks and Tharpe (2002) conducted correlational analyses between unaided PTA and reaction time on a secondary task within a dual-task paradigm. They also examined the relationship between aided PTA (i.e., functional gain) and reaction time. They found no significant relationships between the variables.

However, unaided and aided PTAs have significant limitations as predictors (see Innovation section). Aided SII is a stronger predictor of individual differences in speech recognition and language than PTA (Tomblin et al., 2014). To date, there have been no investigations into how auditory access and cognitive skills influence the effort children must expend when attending to an incoming message while performing additional tasks.

The predictions for this aim are based on the Ease of Language Understanding (ELU) model (Rönnberg et al., 2013). Individuals with a high working memory capacity are able to compensate during complex listening tasks. Although working memory capacity is the primary focus of the adult ELU model, pediatric research indicates vocabulary size may also be important in repairing a distorted signal (Blamey et al., 2001). Thus, I propose that working memory capacity and vocabulary skills influence listening effort, but the strength of this relationship is moderated by auditory access. Alternatively, aided audibility may fully *mediate* the relationship between cognitive-linguistic skills and listening effort, in that cognitive-linguistic variables may not be associated with listening effort after controlling for aided audibility. This alternative hypothesis could occur if peripheral capacity is the sole constraint on listening effort, which would refute the theoretical model. Thus, I will test whether auditory access serves as mediator or moderator in the relationship between cognitive skills and listening effort (MacKinnon, Fairchild, & Fritz, 2007).

Experiment 1: To determine the effects of auditory access and cognitive-linguistic skills on listening effort in school-age children in equated-level and equated-performance listening conditions.

Methods: 60 CHH and 30 CNH (11-12 years) will participate. In Experiment 1A/B, cognitive and linguistic data will be used to predict individual differences in listening effort in CHH in 6 h grade (**Table A**). A subtest of the Automated Working Memory Assessment (AWMA; Alloway, 2007) related to working memory capacity (Counting Recall) will be completed. Counting Recall will be used instead of the more traditional Reading Span task used with adults (Rönnberg et al., 2013) because of its minimal linguistic load. The Peabody Picture Vocabulary Test (PPVT-IV; Dunn & Dunn, 2007) will assess receptive vocabulary. Aided audibility will be considered as a moderating or mediating variable. Behavioral and subjective measures of listening effort will be collected in a dual-task experiment (see General Methods). Training will occur prior to the start of the experiment. Participants will practice the secondary task alone and the dual task with speech stimuli presented at +20 dB SNR. The experimental procedure will consist of primary and secondary tasks administered separately and concurrently: 1) primary auditory task in noise, 2) secondary visual task in quiet, and 3) dual task. The dual task and primary auditory task will be presented at four noise levels. Experimental condition order will be randomized. In the dual-task condition, the examiner will emphasize the importance of the primary task. After each task, participants will rate their perceived levels of effort.

Table A. Predictor variables and moderators

Language	**PPVT-IV**
Working memory	**AWMA-2**: Counting Recall
Audibility	**Aided SII**

1A. Equated-level condition. The purpose of the equated-level condition is to collect data that are comparable to previous listening effort studies in children (Hicks & Tharpe, 2002; Howard et al., 2010), and reflective of real-world listening situations. For the primary task, HINT sentences will be presented at a fixed level of 65 dBA. SNRs of -2, +2, and +6 dB will be used. These SNRs are typical of classroom environments (Crandell & Smaldino, 2000).

1B. Equated-performance condition. The equated-performance condition controls for variance in word recognition performance across children by individualizing the level of testing. For the primary task, HINT sentences will be presented at a fixed level of 65 dBA. The masking noise will be presented at a level at which a participant can understand 50% of speech (SNR-50). Prior to presenting the dual task, I will use an adaptive procedure to obtain the SNR-50, using a one-down, one-up procedure in 2 dB steps (Levitt, 1971).

Data analysis. Primary task performance will be measured as percent-correct (words correct/total words). Secondary task performance will be measured as a difference score to control for variation in baseline reaction times: the median baseline reaction times (RT_B) will be subtracted from the dual-task median reaction times (RT_{DT}) to calculate difference scores ($RT_{DT} – RT_B$). I will use a multiple linear regression analysis with 1) speech recognition percent-correct, 2) reaction time difference scores, and 3) subjective ratings at each of the noise level conditions as the outcome variables. The predictor variables will be working memory capacity and vocabulary. Aided SII will be considered as a moderator/mediator. I will model each predictor variable and each outcome separately. I will also analyze listening effort data across hearing status groups and listening conditions. Primary and secondary task performance and ratings will be analyzed using an analysis of variance (ANOVA), with hearing status as the between-subject variable (CHH vs CNH) and noise levels (-2, +2, +6 dB SNR; SNR-50) as the within-subject variables. This statistical analysis replicates prior research using a similar experimental design (Gosselin & Gagne, 2011). The alpha level will be adjusted using a Bonferroni correction ($\alpha = .0125$). Effect sizes will be calculated as partial eta-squared. LMM will be included for validation of the ANOVA, with hearing status and noise level as fixed effects and random subject effects to account for correlations between multiple observations.

Preliminary data. Fifteen CNH and 3 CHH were tested at -5, 0, and +5 dB SNR (see **Table B**). CNH show the feasibility of the task. There were significant differences in subjective ratings as a function of SNR, with lower ratings (less effort) at +5 dB compared to -5 dB (p = .001), +5 dB compared to 0 dB (p = .03) and 0 dB compared to -5 dB (p = .007). Reaction time on the secondary task at +5 dB SNR was also significantly faster (less effort) than at -5 dB (p = .04). The 3 CHH had the fastest reaction times and lowest ratings at +5 dB, the most favorable condition. At -5 dB, the CHH had a mean percent correct of 19% on the HINT. CHH also showed lower mean ratings than CNH, which suggest the possibility of floor effects at -5 dB for CHH. Based on pilot data, the fixed-level SNRs will be -2, +2, and +6 dB for this experiment.

Table B. Listening effort decreases in easier listening conditions, as shown by faster secondary task reaction times (med. RT_{DT} – med. RT_B in ms) and lower subjective ratings in +5 dB, compared to 0 dB and -5 dB.

		+5 dB	0 dB	-5 dB
Secondary task RT (mean & SD)	CHH	97 (83)	277 (259)	259 (206)
	CNH	139 (148)	170 (237)	278 (235)
Subjective ratings (mean & SD)	CHH	4.3 (2.3)	5.3 (2.1)	6.3 (0.6)
	CNH	4.2 (2.3)	5.5 (2.3)	7.9 (2.2)

Expected outcomes. I predict that children with higher working memory capacity and vocabulary scores will show reduced listening effort compared to children with lower working memory capacity and vocabulary. The relationship between cognitive-linguistic skills and listening effort will be moderated by aided SII. With respect to group differences, listening effort is predicted to vary as a function of hearing status. Specifically, CHH are predicted to expend more listening effort compared to CNH. This prediction is supported by previous research showing a main effect for hearing status (Hicks & Tharpe, 2002). Listening effort is also predicted to vary as a function of listening condition, in that participants will demonstrate more effort in more adverse listening conditions. This prediction is supported by research with CNH, in which performance on the secondary task was significantly better in more favorable SNRs (Howard et al., 2010).

Potential problems. Previous studies showed mixed results with the secondary task on dual-task paradigms with children (Hicks & Tharpe, 2002; Howard et al., 2010). Thus, I will also record participants' verbal response time when repeating sentences by measuring the time between the end of the sentence and the start of the response. Others have used this as an alternative in measuring listening effort (Gustafson et al., 2014). Another issue relates to how incorrect responses on the primary task will be treated. It is possible that children are not attending to the primary stimuli during incorrect responses. Therefore, reaction times will be analyzed by excluding sentences in which the child could not repeat any words in a sentence. Data will also be analyzed including all trials (correct and incorrect responses). Previous research reported no differences in secondary task reaction times when only correct responses are included, compared to correct and incorrect (Hicks & Tharpe, 2002).

Aim 2. To identify the effects of hearing aid use and background noise on listening effort in children who are hard of hearing.

Introduction. HAs are a primary means of aural habilitation for CHH. As such, HAs are predicted to increase a child's access to acoustic cues, thereby reducing listening effort, but this hypothesis has not been fully explored in CHH. The *objective of this aim* is to determine how HA use affects listening effort in CHH in different listening conditions. To attain this objective, I will test the *working hypothesis* that HA use will reduce listening effort in quiet and noise, compared to listening without HAs. This hypothesis will be tested through the *approach* of utilizing a dual-task paradigm in which HA use and listening context are manipulated. The *rationale* for this aim is that these data will provide support for consistent device use and optimizing acoustic conditions in the classroom. This aim builds on my prior work regarding variations in consistency of HA use in CHH, particularly with milder HL.

Justification and feasibility. The current aim seeks to objectively measure listening effort in CHH, with and without HAs. Research suggests that CHH expend more effort in speech recognition tasks compared to CNH (Hicks & Tharpe, 2002). The goal of HAs is to improve audibility in various environments. Although HAs are the primary approach for habilitation for CHH, not all CHH wear their HAs consistently. Furthermore, there is some ambiguity regarding the benefits of HAs for children with milder HL (Fitzpatrick et al., 2010). I have demonstrated wide variability in HA use in CHH during elementary grades (Walker et al., 2013, 2015). At secondary grades, Gustafson et al. (2015) reported that 25% of CHH did not wear their HAs in school. These concerning findings lead to an important research question: does wearing HAs reduce listening effort? Research with adults suggests that HAs can reduce listening effort (Downs, 1982; Hornsby, 2013). It is important to determine whether HAs alleviate listening effort for CHH, given the lack of research examining the negative consequences of reduced HA use in childhood. Increased listening effort results in greater stress, fatigue, and frustration in CHH, relative to hearing peers (Hornsby et al., 2014). Increased fatigue, in turn, has a negative impact on language and academic outcomes (Werfel & Hendricks, 2016). Consistently worn HAs may be a means of reducing listening effort. If the work in this aim proves this to be true, the results will support the importance of encouraging consistent device use in schools.

The predictions for Aim 2 are based on the theoretical ELU model (Ronnberg et al., 2013). If the predictions of the ELU model hold, we will see faster response times on the secondary task with hearing aids on, relative to listening with HAs off. We would also predict that listening in quiet will result in reduced effort compared to listening in background noise, again because of better access to the signal. On the other hand, if HAs do not alleviate listening effort, we will not see a difference in response times on the secondary task or subjective ratings with or without HAs. Such a finding would refute the predictions of the ELU model.

Experiment 2. To determine the effects of HA use and background noise on listening effort.

Methods. 30 CHH (8-11 years) will participate. Participants will wear their own HAs set at preferred settings, based on evidence that adult HA users show more reduced effort when wearing their own HAs (Gatehouse & Gordon, 1990) than when wearing lab-programmed HAs set at unmodified prescriptive targets (Picou et al., 2013). The primary task will be presented in two conditions: quiet and noise. CHH will be presented with HINT sentences. The background noise will be set at 50% performance level without HAs. To avoid floor effects, an equated-performance condition will be used. Participants' verbal responses will be scored by percent-correct in the HINT lists. In situations in which a child's SNR-50 results in the noise being inaudible, the SNR will be fixed at +20 dB. Any participants who have recognition scores less than 15% at 20 dB SNR will be excluded from the analysis due to floor performance (Gatehouse & Gordon, 1990). After obtaining the SNR-50, we will present sentences at that SNR level for dual task and speech recognition-only in four conditions: 1) quiet/unaided, 2) quiet/aided, 3) noise/unaided, and 4) noise/aided, in random order. The secondary task is the same stimuli as Aim 1. Subjective ratings and verbal response time on the primary task will also be collected.

Data analyses. ANOVAs will be conducted with HAs (on vs off) and listening condition (quiet vs noise) as within-subject variables. Reaction time on the secondary task, subjective ratings, and verbal response time will be considered as dependent variables in three separate ANOVAs. LMM will be conducted, with HAs (on vs off) and listening condition (quiet vs noise) as fixed effects and random subject effects to account for correlations between multiple observations.

Preliminary data. Four CHH were tested (not the same as in Aim 1). All four completed the task. One child with severe HL did not reach the SNR-50 criterion, suggesting the paradigm may not be feasible for children with limited unaided audibility. **Fig 2** shows the median reaction time difference (in ms) on the y-axis (individual data and average across subjects) for the 3 CHH who met the SNR criteria. When averaged together, there is a trend of faster reaction times in the quiet/aided condition compared to the noise/unaided condition. The noise/aided condition had faster reaction times (less effort) than the quiet/unaided condition, but the averaged speech recognition scores were the same between these conditions (77%). This supports the scientific premise that reaction time is a more sensitive measure of real-world listening than speech recognition.

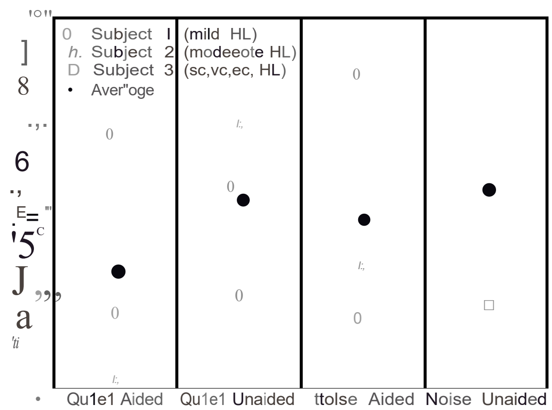

Fig 2. RT difference scores (med RTor - med RTsin ms) for CHH are fastest with HAs and in quiet, suggesting decreased listening effort.

Expected outcomes. Based on previous studies showing that HA use reduces listening effort in adults (Downs, 1982), I predict that there will be main effects for HA use (reduced listening effort with HAs vs no HAs), and listening condition (reduced listening effort in quiet vs noise). Finally, I predict that there will be no interaction between HA use and listening condition, in that HAs will reduce listening effort in both quiet and background noise, consistent with results in adults (Picou et al., 2013).

Potential problems. Some CHH may have difficulty achieving an SNR-50 in which the background noise is still audible. Preliminary data with 67 CHH who completed the BKB-SIN, which uses some of the same stimuli as the HINT, indicates that the average aided SNR-50 was 4.48 dB (SD = 2.73). The unaided SNR-50 should be poorer than the aided SNR-50, but the preliminary data from Subjects 1 and 2 with mild-to-moderate HL suggest noise will still be audible. Children with severe HL may be excluded due to insufficient unaided audibility.

Timeline:

Activity	Pro·ect Year					
	1-1.5	1.5-2	2-2.5	2.5-3	3-3.5	3.5-4
Ai 1 t o e fo (n b)			1	1		
Aim 2 Data Collection (number)	5	10	10	5		
Analysis and Publication of Aim 1						
An l si nd b· tio of Ai						

PROTECTION OF HUMAN SUBJECTS

1. Risks to Subjects. Approximately 30 children with normal hearing and 90 children with hearing loss will participate in this project over the three-year period. Subjects will be between the ages of 8 and 12 years of age at time of participation. Criteria for inclusion of NH children are: 1) normal hearing, 2) at least one hearing parent using spoken English in the home, 3) no evidence of neurodevelopmental or other sensory disorders, 4) nonverbal IQ and articulation skills within normal limits. Criteria for inclusion of children who are hard of hearing in the current study were: 1) mild to severe, bilateral sensorineural, mixed, or permanent conductive hearing loss with better ear pure tone averages ranging from 25-75 dB HL, 2) no evidence of major neurodevelopmental or other sensory disorders, 3) at least one hearing parent using spoken English in the home, 4) nonverbal IQ within normal limits. The total testing hours for children in each aim are described below. We expect to recruit equal numbers of males and females in the NH group.

(Time in Hours)	Aim 1	Aim 2
HH subject burden	2.00	2.00
NH subject burden	2.00	2.00

The data to be collected in the proposed studies will be obtained specifically for research purposes, and is behavioral in nature. In the planned experiments, children will be tested using a combination of audiological tests, dual-task experiments, and standardized tests. Speech recognition testing will be audio recorded for later analysis. For the children with hearing loss, we also will collect routine clinical information concerning the audiogram, middle ear status, and amplification status, in addition to the measures of speech perception and listening effort in quiet and varying levels of background noise.

We can foresee only minimal risk associated with these studies. There are no known psychological or physical risks, with the possible exception of discomfort from the small, flexible tube used during probe microphone testing that is part of electroacoustic hearing aid tests. Adjustments will be made in seating of the tubing if discomfort is evident. As with any study involving human subjects, confidentiality of protected health information is a concern. However, strict procedures for protecting subject confidentiality are in effect. Participants will not be identified by name in reports or publications. Audiotapes will be listened to only by research staff and will be stored in a locked area.

2. Adequacy of Protection Against Risks. The Institutional Review Board of the University of Iowa will review all recruitment materials. At their test visit, participants will complete the informed consent process and any additional questions will be answered at that time. All participants will be paid for their time.

For all of the audiological studies, auditory signals will be kept well below damage risk criteria. If a subject expresses discomfort during the placement of the soft, flexible tube used during probe microphone measures, the tube will be removed and reinserted. Confidentiality will be maintained by storing subject identifiers and data in password protected computer files accessible to the principle investigator and members of the research staff only. The proposed studies will be submitted to and approved by the Institutional Review Board prior to beginning the project.

3. Potential Benefits of the Proposed Research to the Participants and Others. Parents of all enrolled participants will receive feedback regarding their children's participation in the study. All child participants will receive audiological, language and cognitive evaluations in the study. In some cases, the information gathered on children with hearing loss will have relevance to their ongoing clinical/educational programs. With appropriate permissions, the research data will be shared with the child's clinical/educational teams. The benefit that may accrue to society from the proposed research is a better understanding of how mild to severe hearing loss affects child development and educational functioning. The results may support improvements in amplification and intervention strategies for these children.

4. Importance of the Knowledge to be Gained. The proposed research will enhance our understanding of the perceptual and cognitive factors that influence listening effort for children with hearing loss. The results will also provide valuable information on the relative benefits of amplification in varying listening contexts. The importance of the knowledge to be gained is considerable given that the risks to subjects are minimal. These unique analyses address a major gap in the literature on children with hearing loss. In summary, the work is predicted to guide interventions promoting academic achievement for children who are hard of hearing.

INCLLUSION OF WOMEN AND MINORITIES

Inclusion of Women. Child subjects in this project will be 50% female. Adults are not planned as subject participants, however parents of child subjects will be asked to provide background information. For this role, women will be overrepresented as it is typical for mothers to be available as informants on their young children.

Inclusion of Minorities. The number of subjects shown in the Planned Enrollment Table reflects the ethnic/racial composition of the subjects who will be eligible to participate in the 3 year funding period. The percentages of minorities are comparable to the state estimates (according to Census information) and reflects previous recruits from the OCHL study (R01 DC009560) who are eligible for this study.

PHS Inclusion Enrollment Report

This report format should NOT be used for collecting data from study participants.

OMB Number 0925-0001 and 0925-0002
Expiration Date: 10/31/2018

***Study Title:** Mecanisms of Listening Effort in School Age Children who are Hard of Hearing

***Delayed Onset Study?** ❑ Yes ☑ No

If study is not delayed onset, the following selections are required:

Enrollment Type ☑ Planned ❑ Cumulative (Actual)

Using an Existing Dataset or Resource ❑ Yes ☑ No

Enrollment Location ☑ Domestic ❑ Foreign

Clinical Trial ❑ Yes ☑ No

NIH-Defined Phase III Clinical Trial ❑ Yes ☑ No

Comments:

Racial Categories	Ethnic Categories									Total
	Not Hispanic or Latino			Hispanic or Latino			Unknown/Not Reported Ethnicity			
	Female	Male	Unknown/ Not Reported	Female	Male	Unknown/ Not Reported	Female	Male	Unknown/ Not Reported	
American Indian/Alaska Native	0	0		0	0					0
Asian	2	2		0	0					4
Native Hawaiian or Other Pacific Islander	0	0		0	0					0
Black or African American	2	2		0	0					4
White	50	51		3	4					108
More than One Race	3	1		0	0					4
Unknown or Not Reported										
Total	57	56		3	4					120

Report 1 of 1

INCLUSION OF CHILDREN

The primary participants involved in this study are children, ranging in age from 8 to 12 years at time of testing. They will be from two groups: children with normal hearing and children who are hard of hearing. This age range has been chosen based on previous work examining listening effort in children, and pilot testing related to the current proposal.

The principal investigator is a dually certified speech-language pathologist and audiologist. She has specialized in the area of pediatric aural habilitation for the past 15 years, and has vast expertise in working with children in the targeted age range. The Pediatric Audiology Laboratory, where the majority of testing will take place, has been designed to accommodate children. The power analysis described in the Approach section supports the designated number of participants to contribute to meaningful analysis of the proposed study.

REFERENCES CITED

Alloway, T. (2007). *The Automatic Working Memory Assessment* (AWMA). London: Harcourt Assessment.

Anderson, K. L., Goldstein, H., Colodzin, L., & Iglehart, F. (2005). Benefit of S/N enhancing devices to speech perception of children listening in a typical classroom with hearing aids or a cochlear implant. *Journal of Educational Audiology, 12*, 14-28.

ANSI (1997). S3. 5-1997 R-2007, American national standards methods for the calculation of the articulation index. New York: American National Standards Institute.

Arnold, P., & Canning, D. (1999). Does classroom amplification aid comprehension? *British Journal of Audiology*, *33*(3), 171-178.

Bess, F. H., Gustafson, S. J., Corbett, B. A., Lambert, E. W., Camarata, S. M., & Hornsby, B. W. (2016). Salivary Cortisol Profiles of Children with Hearing Loss. *Ear and Hearing*, *37*(3), 334-344.

Blamey, P. J., Sarant, J. Z., Paatsch, L. E., Barry, J. G., Bow, C. P., Wales, R. J., . . . Tooher, R. (2001). Relationships among speech perception, production, language, hearing loss, and age in children with impaired hearing. *Journal of Speech, Language, and Hearing Research, 44*(2), 264-285.

Broadbent, D. E. (1958). Effect of noise on an "intellectual" task. *The Journal of the Acoustical Society of America, 30*(9), 824-827.

Crandell, C. C., & Smaldino, J. J. (2000). Classroom acoustics for children with normal hearing and with hearing impairment. *Language, Speech, and Hearing Services in Schools, 31*(4), 362-370.

Desjardins, J. L., & Doherty, K. A. (2014). The effect of hearing aid noise reduction on listening effort in hearing-impaired adults. *Ear and Hearing*, *35*(6), 600-610.

Downs, D. W. (1982). Effects of hearing aid use on speech discrimination and listening effort. *Journal of Speech and Hearing Disorders, 47*(2), 189-193.

Dunn, D., & Dunn, L. (2007). *Peabody Picture Vocabulary Test-4.* Minneapolis, MN: NCS Pearson Inc.

Eisenberg, L. S., Widen, J. E., Yoshinaga-Itano, C., Norton, S., Thal, D., Niparko, J. K., & Vohr, B. (2007). Current state of knowledge: Implications for developmental research—Key issues. *Ear and Hearing, 28*(6), 773-777.

Finitzo-Hieber, T., & Tillman, T. W. (1978). Room acoustics effects on monosyllabic word discrimination ability for normal and hearing-impaired children. *Journal of Speech, Language, and Hearing Research, 21*(3), 440-458.

Fitzpatrick, E. M., Durieux-Smith, A., & Whittingham, J. (2010). Clinical practice for children with mild bilateral and unilateral hearing loss. *Ear and Hearing, 31*(3), 392-400.

Gatehouse, S., & Gordon, J. (1990). Response times to speech stimuli as measures of benefit from amplification. *British Journal of Audiology, 24*(1), 63-68.

Goldman, R., & Fristoe, M. (2000). *Goldman-Fristoe Test of Articulation 2*. Circle Pines, MN: American Guidance Service.

Gosselin, P. A., & Gagne, J.-P. (2011). Older adults expend more listening effort than young adults recognizing speech in noise. *Journal of Speech, Language, and Hearing Research, 54*(3), 944-958.

Gustafson, S., McCreery, R., Hoover, B., Kopun, J. G., & Stelmachowicz, P. (2014). Listening effort and perceived clarity for normal hearing children with the use of digital noise reduction. *Ear and Hearing, 35*(2), 183-194.

Gustafson, S. J., Davis, H., Hornsby, B. W., & Bess, F. H. (2015). Factors influencing hearing aid use in the classroom: A pilot study. *American Journal of Audiology, 24*(4), 563-568.

Hicks, C. B., & Tharpe, A. M. (2002). Listening effort and fatigue in school-age children with and without hearing loss. *Journal of Speech, Language, and Hearing Research, 45*(3), 573-584.

Holte, L., Walker, E., Oleson, J., Spratford, M., Moeller, M. P., Roush, P., . . . Tomblin, J. B. (2012). Factors influencing follow-up to newborn hearing screening for infants who are hard of hearing. *American Journal of Audiology, 21*(2), 163-174.

Hornsby, B. W. (2013). The effects of hearing aid use on listening effort and mental fatigue associated with sustained speech processing demands. *Ear and Hearing, 34*(5), 523-534.

Hornsby, B. W., Werfel, K., Camarata, S., & Bess, F. H. (2014). Subjective fatigue in children with hearing loss: Some preliminary findings. *American Journal of Audiology, 23*(1), 129-134.

Howard, C. S., Munro, K. J., & Plack, C. J. (2010). Listening effort at signal-to-noise ratios that are typical of the school classroom. *International Journal of Audiology, 49*(12), 928-932.

Kahneman, D. (1973). *Attention and effort*. Englewood Cliffs, NJ: Prentice-Hall.

Levitt, H. (1971). Transformed up-down methods in psychoacoustics. *The Journal of the Acoustical Society of America, 49*(2B), 467-477.
MacKinnon, D. P., Fairchild, A. J., & Fritz, M. S. (2007). Mediation analysis. *Annual Review of Psychology*, *58*, 593-614.
McCreery, R. W., Walker, E. A., Spratford, M., Oleson, J., Bentler, R., Holte, L., & Roush, P. (2015). Speech recognition and parent ratings from auditory development questionnaires in children who are hard of hearing. *Ear and Hearing, 36*, 60S-75S.
McFadden, B., & Pittman, A. (2008). Effect of minimal hearing loss on children's ability to multitask in quiet and in noise. *Language, Speech, and Hearing Services in Schools, 39*(3), 342-351.
Ng, E. H. N., Rudner, M., Lunner, T., Pedersen, M. S., & Rönnberg, J. (2013). Effects of noise and working memory capacity on memory processing of speech for hearing-aid users. *International Journal of Audiology, 52*(7), 433-441.
Niskar, A. S., Kieszak, S. M., Holmes, A., Esteban, E., Rubin, C., & Brody, D. J. (1998). Prevalence of hearing loss among children 6 to 19 years of age: The Third National Health and Nutrition Examination Survey. *Journal of the American Medical Association, 279*(14), 1071-1075.
Pichora-Fuller, M. K., Kramer, S. E., Eckert, M. A., Edwards, B., Hornsby, B. W., Humes, L. E., ... & Naylor, G. (2016). Hearing impairment and cognitive energy: the framework for understanding effortful listening (FUEL). *Ear and Hearing*, *37*, 5S-27S.
Picou, E. M., Ricketts, T. A., & Hornsby, B. W. (2013). How hearing aids, background noise, and visual cues influence objective listening effort. *Ear and Hearing, 34*(5), e52-e64.
Rönnberg, J., Lunner, T., Zekveld, A., Sörqvist, P., Danielsson, H., Lyxell, B., . . . Pichora-Fuller, M. K. (2013). The Ease of Language Understanding (ELU) model: theoretical, empirical, and clinical advances. *Frontiers in Systems Neuroscience, 7*, 1-17.
[redacted] Lunner, T., Behrens, T., Thorén, E. S., & Rönnberg, J. (2012). Working memory capacity may influence perceived effort during aided speech recognition in noise. *Journal of the American Academy of Audiology*, *23*(8), 577-589.
Sarampalis, A., Kalluri, S., Edwards, B., & Hafter, E. (2009). Objective measures of listening effort: Effects of background noise and noise reduction. *Journal of Speech, Language, and Hearing Research*, *52*(5), 1230-1240.
Soli, S. D., & Wong, L. L. (2008). Assessment of speech intelligibility in noise with the Hearing in Noise Test. *International Journal of Audiology, 47*(6), 356-361.
Stiles, D. J., Bentler, R. A., & McGregor, K. K. (2012). The speech intelligibility index and the pure-tone average as predictors of lexical ability in children fit with hearing aids. *Journal of Speech, Language, and Hearing Research, 55*(3), 764-778.
Tomblin, J. B., Harrison, M., Ambrose, S. E., Walker, E. A., Oleson, J. J., & Moeller, M. P. (2015). Language outcomes in young children with mild to severe hearing loss. *Ear and Hearing, 36*, 76S-91S.
Tomblin, J. B., Oleson, J. J., Ambrose, S. E., Walker, E., & Moeller, M. P. (2014). The influence of hearing aids on the speech and language development of children with hearing loss. *JAMA Otolaryngology - Head & Neck Surgery, 140*, 403-409.
Walker, E. A., McCreery, R. W., Spratford, M., Oleson, J. J., Van Buren, J., Bentler, R., . . . Moeller, M. P. (2015). Trends and predictors of longitudinal hearing aid use for children who are hard of hearing. *Ear and Hearing, 36*, 38S-47S.
Walker, E. A., Spratford, M., Moeller, M. P., Oleson, J., Ou, H., Roush, P., & Jacobs, S. (2013). Predictors of hearing aid use time in children with mild-to-severe hearing loss. *Language, Speech, and Hearing Services in Schools, 44*(1), 73-88. 2012
Wechsler, D., & Hsiao-pin, C. (2011). *WASI-II: Wechsler Abbreviated Scale of Intelligence*: Minneapolis, MN: NCS Pearson Inc.
Werfel, K. L., & Hendricks, A. E. (2016). The relation between child versus parent report of chronic fatigue and language/literacy skills in school-age children with cochlear implants. *Ear and Hearing*, *37*(2), 216-224.
[redacted] Stangl, E., Zhang, X., Perkins, J., & Eilers, E. (in press). Psychometric functions of dual-task paradigms for measuring listening effort. *Ear and Hearing.* DOI:10.1097/AUD.0000000000000335

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September 20, 2016

Elizabeth Walker, PhD
Department of Communication Sciences and Disorders
University of Iowa
250 Hawkins Drive, 1258 WJSHC
Iowa City, IA 52242

Dear Dr. Walker:

The purpose of this letter is to state our willingness to support the proposed NIDCD grant entitled *Mechanisms of listening Effort in School-Age Children who are Hard of Hearing.* We have read the specific aimsand acknowledge that this is important research. The results of this research will provide invaluable information that is crucial for us to improve outcomes for children with mild to moderately-severe hearing loss.

As Facilitator for Hearing Services for Heartland Area Education Agency 11, I agree to assist in the referral of study participants, provide testing facilities if needed at our Johnston office and help research staff in whatever ways I can. We have access and contact with many schools and individual families in the central Iowa area, and will forward information about the grant and opportunities to participate to the parents of children who have mild-to-severe hearingloss and areattending school within our agency.

Heartland AEA 11 has a long history of successful collaborative efforts with you and the University of Iowa. We look forward to continued collaboration should this proposal become funded.

Sincerely,

[redacted]

IOWA EAR CENTER
Hearing & Balance
Ear & Skull Base Surgery

12499 University Ave, Suite 200
Clive, IA 50325-8281
Phone: 515-418-9960
888-316-2127
Fax: 515-418-9107

09/18/2016

Elizabeth Walker, PhD
Department of Communication Sciences and Disorders
University of Iowa
250 Hawkins Drive, 1258 WJSHC
Iowa City, IA 52242

Dear Dr. Walker:

The purpose of this letter is to state our willingness to support the proposed NIDCD grant entitled *Mechanisms of Ustening Effort in School-Age Children who are Hard of Hearing.* I have read the specific aims and acknowledge that this is important research. The results of this research will benefit educators and providers in planning appropriate services and programming for thisgroup of students.

As a pediatric audiologist for Iowa Ear Center, I agree to help research staff in whatever ways I can. I have access and contact with families of children who have mild to severe hearing loss within my clinical practice, and will provide information on behalf of the research team.

The Iowa Ear Center has a long history of successful collaborative efforts with youand The University of Iowa. We look forward to continued collaboration once this proposal is funded.

Sincerely,

[redacted]

IIeU LINKDPING UNIVERSITY

DEPARTMENT OF BEHAVIOURAL SOENCES AND LEARNING

Dr. E. Walker

Research proposal: Mechanisms of Listening Effort in School-Age Children who are Hard of Hearing

Dear Dr. Walker

I am very happy to serve as a consultant on your grant: "Mechanisms of Listening Effort in School-Age Children who are Hard of Hearing." I have read your proposal and believe the knowledge generated by the proposed project will be crucial for improving outcomes for children with mild to moderately-severe hearing loss. There is a dearth of knowledge about the cognitive demands associated with listening in this population. Research in adults with hearing loss has shown that listening under adverse conditions makes demands on limited working memory capacity. leaving fewer resources for higher-level cognitive processing of the kind involved in learning. The situation is likely to be similar for children with hearing loss, and because working memory capacity is lower in children than in adults, the effect on learning is likely to be even greater. This means that children with hearing loss are at risk offalling behind in school. It is of the utmost importance to conduct high-quality research that can lead to effective interventions to support these children.

Your project has the potential to supply such knowledge. As such it has high scientific priority. In particular, your project aims to reveal the way in which cognitive and linguistic skills in addition to aided and unaided auditory access, determine listening demands and the ability to multitask in complex auditory environments. The knowledge generated by your research can be applied to the design and implementation of effective educational interventions.

Cognitive Hearing Science is my field of research. I am eager to watch your project come to fruition and I am happy to provide consultation regarding details of design, analysis, and interpretation as the project unfolds.

[redacted]

[redacted]

[redacted]

BOYS TOWN
National Research Hospital

September 10, 2016

Elizabeth Walker, PhD, CCC-SLP/A
Assistant Professor
Department of Communication Sciences and Disorders
University of Iowa, Iowa City IA

Dear Elizabeth:

As the Director of the Center for Audiology at Boys Town National Research Hospital, I agree to assist in the referral of study participants and provide testing facilities as needed at Boys Town National Research Hospital. I have access and contact with families of children who have mild to severe hearing loss within my clinical practice, and will provide information on behalf of the research team.

Sincerely,

[redacted]

[redacted]

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200 Hawkins Drive, 21200 PFP
Iowa City, Iowa 52242 1081
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September 16, 2016

Elizabeth Walker, PhD
Department of Communication Sciences and Disorders
University oflowa
250 Hawkins Drive, 125B WJSHC
Iowa City, IA 52242

Dear Dr. Walker:

The purpose of this letter is to state our willingness to support the proposed NIDCD grant entitled *Mechanisms of Listening Effort in School-Age Children who are Hard of Hearing.* I have read the specific aims and acknowledge that this is important research. The results of this research will benefit educators and providers in planning appropriate services and programming for this group of students.

As Director of the Hearing Aid Center at the University of Iowa Hospitals and Clinics, I agree to assist in the refe1Tal of study participants and help research staff in whatever ways I can. I have access and contact with families of children who have mild to severe hearing loss within my clinical practice, and will provide information on behalf of the research team.

The UIHC has a long history of successful collaborative efforts with you and The University of Iowa. We look forward to continued collaboration once this proposal is funded.

Sincerely,

[redacted]

THE UNIVERSITY OF IOWA

COLLEGE OF LIBERAL ARTS & SCIENCES
Department of Communication Sciences and Disorders
Wendell Johnson Speech and Hearing Center
119 WJSHC
Iowa City, Iowa 52242-1012
319·335·8718 *Fax* 319·335·8851

September 21, 2016

Dear Dr. Walker:

I am very happy to serve as a consultant on your grant: "Mechanisms of Listening Effort in School-Age Children who are Hard of Hearing." I have read your proposal and believe it will provide invaluable information that is crucial for us to improve outcomes for children with mild to moderately-severe hearing loss. This is a population of hearing-impaired children that has been underrepresented in the research on the impact of hearing loss on listening effort. It is particularly important and informative to conduct studies that identify factors that may reduce the negative effects of effortful listening for children who are hard of hearing, who are primarily educated in mainstream classroom environments.

Your project will supply essential information on factors related to aided and unaided auditory access, as well as cognitive and linguistic skills that are major determinants of how children with hearing loss manage listening demands and multitasking in complex auditory environments. This information is vital for the future design and implementation of effective and research-based educational and technological interventions.

I am also willing to provide you with any materials and procedures that I have found to be helpful in the measurement of listening effort. My areas of research expertise have focused on understanding how laboratory tests and retrospective self-reports such as questionnaires reflect the actual effect of hearing aids, and on identifying problems/factors that can prevent or reduce use and benefit of hearing aids for older adults. I will be happy to provide consultation regarding details of further design, analyses, and interpretation matters as the project unfolds.

Sincerely,

[redacted]

Mechanisms of Listening Effort in School-Age Children who are Hard of Hearing

DATA SHARING PLAN

The proposed research will include data from approximately 90 subjects with mild to severe hearing loss and 30 normal hearing age mates. The final dataset will include parent-reported demographic data and data collected from standardized and experimental measures conducted with the subjects. These data will be made available to users via a data enclave at the University of Chicago www.norc.org or a similar data enclave at the University of Michigan www.icpsr.umich.edu. For both data sets (NORC or UMICH) the final data will be stripped of identifiers prior to release for sharing. Thus, the PI will make the data and associated documentation available to users only under a data-sharing agreement that provides for: (1) a commitment to using the data only for research purposes and not to identify any individual participant; (2) a commitment to securing the data using appropriate computer technology; and (3) a commitment to destroying or returning the data after analyses are completed. Registered users will receive user support and publication lists. The information provided to users will *not* be used for commercial purposes, and will *not* be redistributed to third parties.