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TITLE: Identifying the Sources of Degraded Speech-in-Noise Understanding and Individualized Therapeutic Options

PRINCIPAL INVESTIGATOR: Inyong Choi, Ph.D.

CONTRACTING ORGANIZATION: University of Iowa, Iowa City, IA

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Fort Detrick, Maryland 21702-5012

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REPORT DOCUMENTATION PAGE

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4. TITLE AND SUBTITLE

Identifying the Sources of Degraded Speech-in-Noise Understanding and Individualized Therapeutic Options

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5b. GRANT NUMBER
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5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
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5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
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Iowa City, IA 52242-1320

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13. SUPPLEMENTARY NOTES

14. ABSTRACT

This project will identify the peripheral and central factors that predict the variance of speech-in-noise (SiN) understanding ability among normal hearing listeners. To achieve this goal, in Aim 1, neural substrates of all the key stages along the proposed SiN processing model will be characterized through within-subject design experiments of human electrophysiology. In Aim 2, a correlational study, we will characterize a hierarchical regression model that adopts the measures of auditory neural processes as independent variables and electrophysiological responses and behavioral performance during phonological and lexical processing as dependent variables. Finally, Aim 3 will seek an optimal, clinically applicable set of test batteries and measures that identifies 1) the sources of degraded speech-in-noise understanding and 2) the most effective, individualized therapeutic options.

15. SUBJECT TERMS
None listed.

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
Unclassified					USAMRDC
a. REPORT	b. ABSTRACT	c. THIS PAGE	Unclassified	16	19b. TELEPHONE NUMBER *(include area code)*
Unclassified	Unclassified	Unclassified			

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18

TABLE OF CONTENTS

1. **INTRODUCTION:** *Narrative that briefly (one paragraph) describes the subject, purpose and scope of the research.*

   The ability to understand speech in noisy real-world settings varies even among young healthy people with normal hearing thresholds. However, current audiology practice does not provide diagnostics or treatment for speech-in-noise (SiN) problems in normal hearing listeners. This project aims to identify peripheral and central factors that predict the variance of SiN understanding ability among normal hearing listeners. To achieve this goal, Aim 1 characterizes neural substrates of several key auditory functions that contribute to successful SiN understanding using within-subject design experiments of human electrophysiology. Aim 2 will characterize a hierarchical regression model that predicts individual listeners' SiN performance using the following predictor variables: The measures of peripheral encoding, auditory grouping, auditory memory, and selective attention processes. Finally, Aim 3 will seek an optimal, clinically applicable set of test batteries that identifies 1) the sources of degraded speech-in-noise understanding and 2) the most effective, individualized therapeutic options. This study will characterize several key neural processes required for successful speech understanding in social settings, and will promote our understanding of how peripheral and central processing contribute to successful SiN understanding.

2. **KEYWORDS:** *Provide a brief list of keywords (limit to 20 words).*

   Speech in noise, peripheral auditory encoding, auditory grouping, auditory selective attention, phonological processing, lexical processing, electroencephalography (EEG), electrocorticography (ECoG)

3. **ACCOMPLISHMENTS:** *The PI is reminded that the recipient organization is required to obtain prior written approval from the awarding agency grants official whenever there are significant changes in the project or its direction.*

   What were the major goals of the project?
   List the major goals of the project as stated in the approved SOW. If the application listed milestones/target dates for important activities or phases of the project, identify these dates and show actual completion dates or the percentage of completion.

   This is the fourth-year annual report. By the fourth year, this project aimed to complete the following studies:

   1. Aim 1: Within-subject study to characterize neural mechanisms of auditory grouping: 1) With scalp EEG in normal subjects and 2) with electrocorticography (ECoG) in epilepsy patients.
   2. Aim 1: Within-subject study to characterize neural mechanisms of selective attention: 1) With scalp EEG in normal subjects and 2) with ECoG in epilepsy patients.
   3. Aim 1: Within-subject study to investigate the effect of neurofeedback attention training on speech-in-noise perception: 1) With scalp EEG in normal subjects and 2) with ECoG in epilepsy patients.
   4. Aim 2: Correlational study to characterize the relationship between the fidelity of peripheral auditory encoding [measured by medial olivo-cochlear reflex (MOCR), middle ear muscle

reflex (MEMR), and auditory brainstem responses (ABR)] and speech-in-noise performance.

5. Aim 2: Correlational study to characterize the relationship between auditory grouping ability and speech-in-noise performance
6. Aim 2: Correlational study to characterize the relationship between selective attention ability and speech-in-noise performance
7. Aim 3: Finding the optimal layout of EEG electrodes for the assessment of neural processing for speech-in-noise
8. Aim 3: Comparing signal qualities between dry and wet EEG electrodes

What was accomplished under these goals?

For this reporting period describe: 1) major activities; 2) specific objectives; 3) significant results or key outcomes, including major findings, developments, or conclusions (both positive and negative); and/or 4) other achievements. Include a discussion of stated goals not met. Description shall include pertinent data and graphs in sufficient detail to explain any significant results achieved. A succinct description of the methodology used shall be provided. As the project progresses to completion, the emphasis in reporting in this section should shift from reporting activities to reporting accomplishments.

1) Major activities

We have conducted within-subject studies from 120 EEG subjects and 7 ECoG subjects, which nearly completes the data collection goal at the end of Year 4 for the EEG portion. Currently we are at the 96.2% point of the total data collection goal.

In Year 4, based on our interim results from the data we have collected so far, we published four peer-reviewed research articles. Also, another manuscript is under a minor revision. These make total ten peer-reviewed research articles published and one article under a minor revision during the whole grant period. We acknowledged federal funding in all the published articles.

Key outcomes from the data analysis and the list of publications are described in the following sub-sections (including Section 3: Significant results and key outcomes).

2) Specific objectives

Objectives of the Aims 1 and 2 within- and across-subject studies were to identify neural markers of speech-in-noise variance in normal hearing listeners. The object of Aim 3 was finding efficient scalp EEG electrode layouts that effectively captures neural predictors of speech-in-noise ability.

3) Significant results and key outcomes

Our key outcome is a regression model that predicts individual listeners' speech-in-noise performance using the measures of peripheral and central auditory processing.

Background. Many studies in the last decade contributed to explaining the large variance in normal hearing listeners' abilities to understand speech in noise. Those studies revealed several factors associated with the speech-in-noise variance such as outer hair cell damages, distorted cochlear tonotopy, the loss of auditory nerve fibers, poorer auditory grouping, and attention and

memory deficits. However, a clear diagnostic method that identifies the source of speech-in-noise variance is yet to be established.

Current limitation of the model that explains normal hearing listeners' speech-in-noise variance is due to several difficulties. First, "normal hearing listeners" do not yield consistent variance across different bivariate studies. Second, the outcome variable (abilities to understand speech in noise) is multi-dimensional and not well defined. Third, the hierarchy and redundancy of the factors that impact the outcome variable is unknown, which prevents selecting the right modeling equation.

Method. We tried to resolve the above difficulties. First, we setup clear criteria for recruiting three different "normal hearing" cohorts: musicians, noise exposed non-musicians, and non-noise exposed individuals. All participants had normal standard audiograms with thresholds at or below 20dB HL from 250-8,000Hz. These cohorts were recruited separately but treated as a single continuous group in the analyses. Through this divided recruitment and merging, we obtained a considerable variance in the degree of auditory skills and peripheral damages even in age-controlled subjects with normal hearing thresholds (See **Figure 1**). Second, we captured a holistic measure speech-in-noise ability by combining a single word-based speech-in-noise test, a sentence-based test, and a self-report of speech-in-noise difficulties. Third, we conducted extensive tests of subcortical and cortical auditory functions including extended high-frequency audiometry, distortion product otoacoustic emissions, middle ear muscle reflex, medial olivo-cochlear reflex, auditory brainstem responses, and cortical activities during auditory working memory and attention tasks.

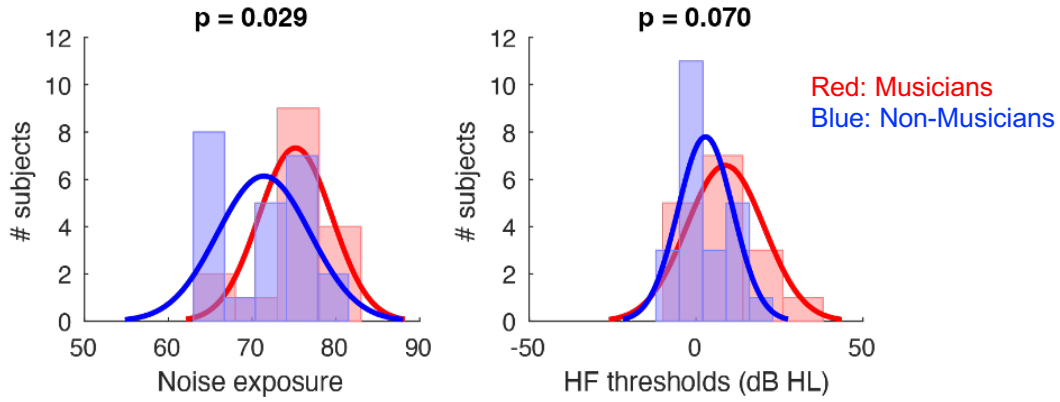

Figure 1. Musicians extended the variance of independent variables, exhibiting disadvantages in peripheral hearing as they tend to have greater noise exposure and elevated high frequency thresholds.

To measure cortical activities during auditory working memory and attention tasks, we conducted the following experiment. The test two conditions: "Voice" and "Space" conditions. An auditory verbal cue "Choose the word" was given as the first event of a trial in both conditions. In the Space condition, Participants were tasked with remembering the direction of the cue (left, center, or right), then select the word that is spoken in the same direction. In the Voice condition, participants were asked to remember who said the cue (man, woman, child), then select the word that is spoken by the same talker. See **Figure 2** for the trial structure.

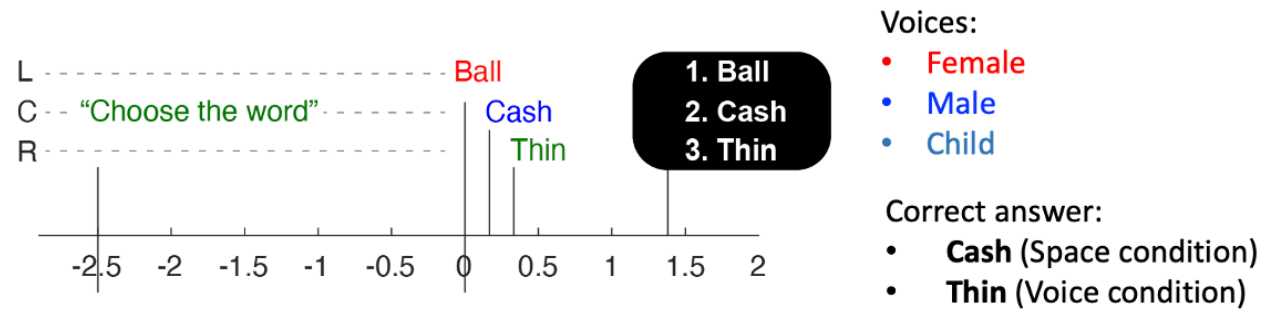

Figure 2. Trial structure of the Space & Voice-based attention & memory task.

Result. Although most bivariate correlation analyses failed showing significant association between a single independent and predictor variable, extended high-frequency thresholds exhibited significant correlation with speech-in-noise performance (See **Figure 3**).

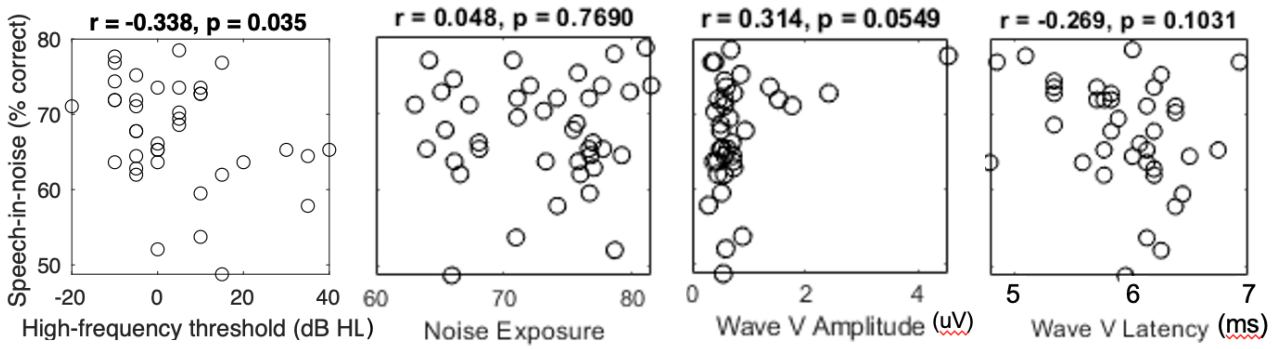

Figure 3. Correlations of selected peripheral measures and speech-in-noise score

In contrast, the measures of cortical processing for auditory attention and memory showed significant correlation with the speech-in-noise performance. **Figure 4** shows EEG event related spectral perturbation during the Voice condition compared to the Space condition. In the voice condition, temporal lobe exhibits delta & theta (2-7Hz) oscillation during retention period. This low-frequency oscillation is related with top-down process of auditory working memory.

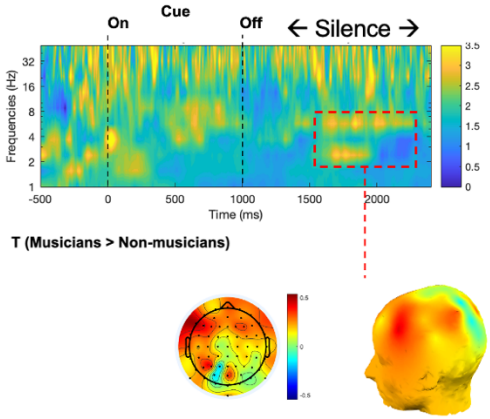

Figure 4. EEG event related spectral perturbation during the Voice-based attention task.

The low-frequency cortical oscillation during the Voice attention condition showed significant correlation with speech-in-noise performance (See **Figure 5**).

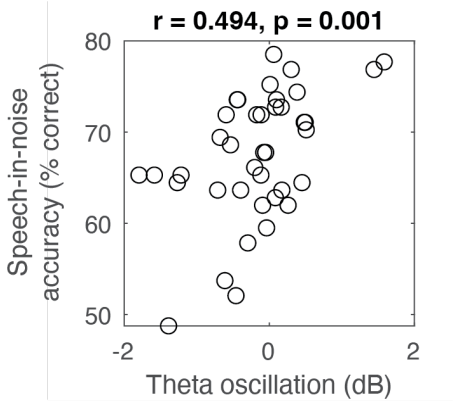

Figure 5. Theta-oscillatory power during the retention of voice identity / preparation of selective attention is correlated with speech-in-noise performance

Conclusion. Combining the measures of peripheral processing (i.e., extended high-frequency thresholds) and the measures of central auditory processing (i.e., theta-oscillation during auditory attention & memory task), the predictor variables explained about 41% of speech-in-noise variance in normal hearing listeners. Recruiting musicians extend the variance in both predictors and dependent variables. These results indicate that both peripheral and central factors matter for speech-in-noise, thus the diagnostics for speech-in-noise ability in normal hearing listeners must adopt the both measures.

What opportunities for training and professional development has the project provided?
If the project was not intended to provide training and professional development opportunities or there is nothing significant to report during this reporting period, state "Nothing to Report."

Describe opportunities for training and professional development provided to anyone who worked on the project or anyone who was involved in the activities supported by the project. "Training" activities are those in which individuals with advanced professional skills and experience assist others in attaining greater proficiency. Training activities may include, for example, courses or one-on-one work with a mentor. "Professional development" activities result in increased knowledge or skill in one's area of expertise and may include workshops, conferences, seminars, study groups, and individual study. Include participation in conferences, workshops, and seminars not listed under major activities.

This project has been providing research experiences to two post-doctoral research scientists, three PhD students, three graduate (Doctor of Audiology) students, and two undergraduate students. The provided research experiences include EEG, ECoG, and behavioral data collection from human subjects, theoretical training of hearing science, and computational analyses of electrophysiological data.

How were the results disseminated to communities of interest?
If there is nothing significant to report during this reporting period, state "Nothing to Report."

Describe how the results were disseminated to communities of interest. Include any outreach activities that were undertaken to reach members of communities who are not usually aware of these project activities, for the purpose of enhancing public understanding and increasing interest in learning and careers in science, technology, and the humanities.

Nothing to report.

What do you plan to do during the next reporting period to accomplish the goals?
If this is the final report, state "Nothing to Report."

Describe briefly what you plan to do during the next reporting period to accomplish the goals and objectives.

In the next project year, we are planning to finish data collection for all three aims. Based on the findings, we will submit three additional manuscripts to peer-reviewed journals. The very next manuscript that describes differential neural mechanisms of space- and speaker identity-based auditory selective attention is currently being prepared for the submission. The second next manuscript will describe the multiple regression model to predict speech-in-noise performance using peripheral and central auditory factors. The third manuscript will expand our findings from the neurofeedback training of auditory selective attention.

4. **IMPACT:** D*escribe distinctive contributions, major accomplishments, innovations, successes, or any change in practice or behavior that has come about as a result of the project relative to:*

What was the impact on the development of the principal discipline(s) of the project?
If there is nothing significant to report during this reporting period, state "Nothing to Report."

Describe how findings, results, techniques that were developed or extended, or other products from the project made an impact or are likely to make an impact on the base of knowledge, theory, and research in the principal disciplinary field(s) of the project. Summarize using language that an intelligent lay audience can understand (Scientific American style).

This year's key findings demonstrated that speech-in-noise ability can be predicted by the measures of peripheral and central auditory processes. We developed the right test environments and tasks that successfully represent such auditory functions. In the future, we will be able use these measures as a clinical monitoring tool for hearing intervention.

What was the impact on other disciplines?
If there is nothing significant to report during this reporting period, state "Nothing to Report."

Describe how the findings, results, or techniques that were developed or improved, or other products from the project made an impact or are likely to make an impact on other disciplines.

Nothing to report.

What was the impact on technology transfer?
If there is nothing significant to report during this reporting period, state "Nothing to Report."

Describe ways in which the project made an impact, or is likely to make an impact, on commercial technology or public use, including:

- *transfer of results to entities in government or industry;*
- *instances where the research has led to the initiation of a start-up company; or*
- *adoption of new practices.*

Nothing to report.

What was the impact on society beyond science and technology?
If there is nothing significant to report during this reporting period, state "Nothing to Report."

Describe how results from the project made an impact, or are likely to make an impact, beyond the bounds of science, engineering, and the academic world on areas such as:

- *improving public knowledge, attitudes, skills, and abilities;*
- *changing behavior, practices, decision making, policies (including regulatory policies), or social actions; or*
- *improving social, economic, civic, or environmental conditions.*

Nothing to report.

5. **CHANGES/PROBLEMS:** *The PD/PI is reminded that the recipient organization is required to obtain prior written approval from the awarding agency grants official whenever there are significant changes in the project or its direction. If not previously reported in writing, provide the following additional information or state, "Nothing to Report," if applicable:*

Changes in approach and reasons for change
Describe any changes in approach during the reporting period and reasons for these changes. Remember that significant changes in objectives and scope require prior approval of the agency.

Nothing to report.

Actual or anticipated problems or delays and actions or plans to resolve them
Describe problems or delays encountered during the reporting period and actions or plans to resolve them.

Because human subject research was suspended university-wide due to the COVID-19 pandemic in Years 1 and 2, data collection was slower than expected. To achieve all the planned research goals, the secondary no-cost extension of project period has been requested and approved. Under the revised plan, we will achieve 12 ECoG subjects by the second quarter of Year 4. The final large-cohort regression analyses and disseminations of results will be performed throughout Year 5.

Changes that had a significant impact on expenditures

Describe changes during the reporting period that may have had a significant impact on expenditures, for example, delays in hiring staff or favorable developments that enable meeting objectives at less cost than anticipated.

Nothing to report.

Significant changes in use or care of human subjects, vertebrate animals, biohazards, and/or select agents

Describe significant deviations, unexpected outcomes, or changes in approved protocols for the use or care of human subjects, vertebrate animals, biohazards, and/or select agents during the reporting period. If required, were these changes approved by the applicable institution committee (or equivalent) and reported to the agency? Also specify the applicable Institutional Review Board/Institutional Animal Care and Use Committee approval dates.

Significant changes in use or care of human subjects

None

Significant changes in use or care of vertebrate animals

Not applicable.

Significant changes in use of biohazards and/or select agents

Not applicable.

6. **PRODUCTS:** *List any products resulting from the project during the reporting period. If there is nothing to report under a particular item, state "Nothing to Report."*

- **Publications, conference papers, and presentations**
  Report only the major publication(s) resulting from the work under this award.

Journal publications. *List peer-reviewed articles or papers appearing in scientific, technical, or professional journals. Identify for each publication: Author(s); title; journal; volume: year; page numbers; status of publication (published; accepted, awaiting publication; submitted, under review; other); acknowledgement of federal support (yes/no).*

During the report period (Sep 2022 – Aug 2023), four peer-reviewed research artilcles have been published in peer reviewed journals. One more manuscript is under a minor revision now:

1. Shim, H., Gibbs, L., Rush, K., Ham, J., Kim, S., Kim, S., & Choi, I. (2023). Neural Mechanisms Related to the Enhanced Auditory Selective Attention Following Neurofeedback Training: Focusing on Cortical Oscillations. Applied Sciences, 13(14), 8499. Acknowledgement of federal support: Yes.
2. Berger, J. I., Phillip E. Gander, Subong Kim, Adam T. Schwalje, Jihwan Woo, Young-min Na, Ann Holmes, Jean Hong, Camille Dunn, Marlan Hansen, Bruce Gantz, Bob McMurray, Timothy D. Griffiths, Inyong Choi. (2023). Neural correlates of individual differences in speech-in-noise performance in a large cohort of cochlear implant users. Ear and Hearing. 10.1097/AUD.0000000000001357. Acknowledgement of federal support: Yes.
3. Lee, J-H., Shim, H., Gantz, B., Choi, I. (2022). Strength of Attentional Modulation on Cortical Auditory Evoked Responses Correlates with Speech-in-Noise Performance in Bimodal Cochlear Implant Users. Trends in Hearing. 26, 23312165221141143. Acknowledgement of federal support: Yes.
4. Shim, H., Kim, S., Hong, J., Na, Y., Woo, J., Hansen, M., Gantz, B., Choi, I. (2022). Differences in neural encoding of speech in noise between cochlear implant users with and without preserved acoustic hearing. Hearing Research. 108649. Acknowledgement of federal support: Yes.
5. Inyong Choi, Phillip E. Gander, Joel I. Berger, Matthew H. Choy, Jean Hong, Sarah Colby, Bob McMurray, and Timothy D. Griffiths. Spectral grouping of electrically encoded sound predicts speech-in-noise performance in cochlear implantees. Submitted to the Journal of Association for Research in Otolaryngology (JARO). Under a minor revision. Acknowledgement of federal support: Yes.

Books or other non-periodical, one-time publications. *Report any book, monograph, dissertation, abstract, or the like published as or in a separate publication, rather than a periodical or series. Include any significant publication in the proceedings of a one-time conference or in the report of a one-time study, commission, or the like. Identify for each one-time publication: author(s); title; editor; title of collection, if applicable; bibliographic information; year; type of publication (e.g., book, thesis or dissertation); status of publication (published; accepted, awaiting publication; submitted, under review; other); acknowledgement of federal support (yes/no).*

Nothing to report.

Other publications, conference papers and presentations. *Identify any other publications, conference papers and/or presentations not reported above. Specify the status of the publication as noted above. List presentations made during the last year (international, national, local societies, military meetings, etc.). Use an asterisk (*) if presentation produced a manuscript.*

Conference presentation (6):
The following presentations have been made at the Association for Research in Otolaryngology (ARO) meeting (Feb 2023):

1. Jusung Ham, Leah Gibbs, Karsyn Rush, Hwan Shim, Inyong Choi, "Effect of Feedback Reliability for Neurofeedback Training of Auditory Selective Attention"
2. Inyong Choi, "Binaural Phenomena in Asymmetric Hearing"
3. Francis Smith, Phillip Gander, Joel Berger, Jean Hong, Bob McMurray, Timothy Griffiths, and Inyong Choi, "Plasticity in Recent Cochlear Implantees' Cortical Response to Speech and to Noise"
4. Nour Alsabbagh, Timothy Griffiths, Bob McMurray, Inyong Choi, Phillip Gander, "Neural Signatures of Predictive Coding During Auditory Temporal Coherence Detection in Cochlear Implant Users"
5. Hwan Shim, Subong Kim, Leah Gibbs, Karsyn Rush, Sungyoung Kim, Inyong Choi, "Changes in the Oscillatory Activity of Executive Attentional Networks Following Neurofeedback Training of Auditory Selective Attention"
6. Kayla Howerton, Jusung Ham, Inyong Choi, Shawn Goodman, "Investigating Normal Hearing Listeners' Variance in Speech-In-Noise Understanding: Difficulties and Resolutions"

- **Website(s) or other Internet site(s)**
List the URL for any Internet site(s) that disseminates the results of the research activities. A short description of each site should be provided. It is not necessary to include the publications already specified above in this section.

Nothing to report.

- **Technologies or techniques**
Identify technologies or techniques that resulted from the research activities. Describe the technologies or techniques were shared.

Nothing to report.

- **Inventions, patent applications, and/or licenses**
Identify inventions, patent applications with date, and/or licenses that have resulted from the research. Submission of this information as part of an interim research performance progress report is not a substitute for any other invention reporting required under the terms and conditions of an award.

Nothing to report.

- **Other Products**

  Identify any other reportable outcomes that were developed under this project. Reportable outcomes are defined as a research result that is or relates to a product, scientific advance, or research tool that makes a meaningful contribution toward the understanding, prevention, diagnosis, prognosis, treatment and /or rehabilitation of a disease, injury or condition, or to improve the quality of life. Examples include:

  - *data or databases;*
  - *physical collections;*
  - *audio or video products;*
  - *software;*
  - *models;*
  - *educational aids or curricula;*
  - *instruments or equipment;*
  - *research material (e.g., Germplasm; cell lines, DNA probes, animal models);*
  - *clinical interventions;*
  - *new business creation; and*
  - *other.*

  Nothing to report.

7. PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

What individuals have worked on the project?

Provide the following information for: (1) PDs/PIs; and (2) each person who has worked at least one person month per year on the project during the reporting period, regardless of the source of compensation (a person month equals approximately 160 hours of effort). If information is unchanged from a previous submission, provide the name only and indicate "no change".

Example:	
Name:	*Mary Smith*
Project Role:	*Graduate Student*
Researcher Identifier (e.g. ORCID ID):	*1234567*
Nearest person month worked:	*5*
Contribution to Project:	*Ms. Smith has performed work in the area of combined error-control and constrained coding.*
Funding Support:	*The Ford Foundation (Complete only if the funding support is provided from other than this award.)*

Name: Inyong Choi
Project Role: PI
Researcher Identifier: ORCID 0000-0002-6663-9152
Nearest person months worked: 3

Contribution to Project: Conducting all the research activities.

Name: Phillip Gander
Project Role: Co-investigator
Researcher Identifier: ORCID 0000-0003-3945-8820
Nearest person months worked: 1
Contribution to Project: Developed stimuli and experiment scripts for the ECoG study.

Name: Sungyoung Kim
Project Role: Subaward PI
Nearest person months worked: 3
Contribution to Project: Developed a wireless EEG system (Aim 3).

Has there been a change in the active other support of the PD/PI(s) or senior/key personnel since the last reporting period?
If there is nothing significant to report during this reporting period, state "Nothing to Report."

If the active support has changed for the PD/PI(s) or senior/key personnel, then describe what the change has been. Changes may occur, for example, if a previously active grant has closed and/or if a previously pending grant is now active. Annotate this information so it is clear what has changed from the previous submission. Submission of other support information is not necessary for pending changes or for changes in the level of effort for active support reported previously. The awarding agency may require prior written approval if a change in active other support significantly impacts the effort on the project that is the subject of the project report.

Nothing to report.

What other organizations were involved as partners?
If there is nothing significant to report during this reporting period, state "Nothing to Report."

Describe partner organizations – academic institutions, other nonprofits, industrial or commercial firms, state or local governments, schools or school systems, or other organizations (foreign or domestic) – that were involved with the project. Partner organizations may have provided financial or in-kind support, supplied facilities or equipment, collaborated in the research, exchanged personnel, or otherwise contributed.

Provide the following information for each partnership:
Organization Name:
Location of Organization: (if foreign location list country)
Partner's contribution to the project (identify one or more)

- *Financial support;*
- *In-kind support (e.g., partner makes software, computers, equipment, etc., available to project staff);*
- *Facilities (e.g., project staff use the partner's facilities for project activities);*

- *Collaboration (e.g., partner's staff work with project staff on the project);*
- *Personnel exchanges (e.g., project staff and/or partner's staff use each other's facilities, work at each other's site); and*
- *Other.*

Organization Name: Rochester Institute of Technology
Location of Organization: Rochester, NY
Partner's contribution to the project: Collaboration.

8. SPECIAL REPORTING REQUIREMENTS

COLLABORATIVE AWARDS: *For collaborative awards, independent reports are required from BOTH the Initiating Principal Investigator (PI) and the Collaborating/Partnering PI. A duplicative report is acceptable; however, tasks shall be clearly marked with the responsible PI and research site. A report shall be submitted to* ***https://ers.amedd.army.mil*** *for each unique award.*

QUAD CHARTS: *If applicable, the Quad Chart (available on https://www.usamraa.army.mil) should be updated and submitted with attachments.*

9. APPENDICES: *Attach all appendices that contain information that supplements, clarifies or supports the text. Examples include original copies of journal articles, reprints of manuscripts and abstracts, a curriculum vitae, patent applications, study questionnaires, and surveys, etc.*