

**AWARD NUMBER:** W81XWH-19-1-0367

**TITLE:** Toward Development of a Mobile Assessment and Differential Diagnosis of Auditory Dysfunction: Hidden Hearing Loss and Central Auditory Processing Disorders

**PRINCIPAL INVESTIGATOR:** Dr. Michelle Molis

**CONTRACTING ORGANIZATION:** VA Portland Health Care System – NCRAR,  
Portland, OR

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# REPORT DOCUMENTATION PAGE

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<b>13. SUPPLEMENTARY NOTES</b>						
<b>14. ABSTRACT</b>  The short-term objective of this proposal is to examine the utility of a recently-developed test measure called Time Compressed Digits (TCD) to reveal auditory dysfunction by examining relationships between performance on the TCD, self-reported hearing difficulties, and laboratory assessments of "hidden hearing loss" (HHL) and auditory processing disorders (APD). The proposed research will test Veterans separated from the military within the previous five years with no more than a mild hearing loss as a preliminary step toward further test development in both active-duty and clinical populations. Performance on the TCD task will be related to self-reported difficulties with hearing in everyday life as measured by the Speech, Spatial and Qualities of Hearing Scale (SSQ-12). Additionally, based on auditory behavioral and electrophysiological assessment, a statistical model will be developed to predict deficits in outer hair cell function, synaptic/neuronal function, central auditory processing, and working memory based on an individual's age and their performance on the TCD task. Development of an objective and simple-to-administer test of speech understanding that is sensitive to subtle impairments in the auditory system would provide VA audiologists with evidence-based guidance for assessing the communication difficulties of Veterans without significant threshold shifts who nevertheless report increased listening effort or difficulty in challenging listening situations.						
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## 1. INTRODUCTION:

The purpose of this study is to develop a screening tool to identify Veterans with hearing problems that are not detected by standard clinical hearing tests. Development of an objective and simple-to-administer test of speech understanding that is sensitive to subtle impairments in the auditory system would provide VA audiologists with evidence-based guidance for assessing the communication difficulties of Veterans without significant threshold shifts who nevertheless report increased listening effort or difficulty in challenging listening situations. This will be done by comparing an individual's performance on a test called Time Compressed Digits (TCD) with their self-reported hearing difficulties, as measured by the Speech, Spatial and Qualities of Hearing Scale (SSQ-12), to determine if this test is a good reflection of hearing abilities in everyday life. Additionally, based on auditory behavioral and electrophysiological assessment, a statistical model will be developed to predict deficits in outer hair cell function, synaptic/neuronal function, central auditory processing, and working memory based on an individual's age and their performance on the TCD task.

## 2. KEYWORDS:

hearing loss, sensorineural; hearing loss, central; speech understanding; hidden hearing loss; Veterans; hearing difficulties; synaptopathy; central auditory processing; working memory

## 3. ACCOMPLISHMENTS:

### What were the major goals of the project?

The **long-term objective** of this research is development of an auditory screening tool for identification of suprathreshold auditory deficits that will also provide an initial differential diagnosis of the type of auditory dysfunction in order to guide follow-up assessment. The **short-term objective** of this proposal is to examine the utility of a recently developed test measure called Time Compressed Digits (TCD) to reveal auditory dysfunction by examining relationships between performance on the TCD, self-reported hearing difficulties, and laboratory assessments of hidden hearing loss (HHL) and auditory processing disorders (APD).

Specific Aim 1: Determine how performance on the TCD test corresponds to Veterans' self-reported difficulties with hearing in everyday life as measured by the 12-item version of the Speech, Spatial and Qualities of Hearing Scale (SSQ12).

Specific Aim 2: Develop a statistical model to predict deficits in outer hair cell (OHC) function, synaptic/neuronal function, central auditory processing, and working memory based on an individual's age and their performance on the TCD task.

	<b>Timeline Months</b>	<b>% Completion</b>
<b>Major Task 1: Prepare for subject recruitment and testing</b>		
Subtask 1: IRB Approval	1-3	100
Subtask 2: HRPO Approval	1-3	100
Subtask 3: Purchase test materials and supplies	1-3	95*
Subtask 4: Purchase equipment and computer	1-3	90*
Subtask 5: Set up IHS system	4	100
Subtask 6: Hire Research Assistant (RA)	1	100
Subtask 7: Modify TCD computer program	4	100
Milestone(s) Achieved: Approvals obtained, purchases competed, lab set up completed, RA hired and added to IRB, TCD program modified to present specified test conditions	5	97*
<b>Major Task 2: Data collection</b>		
Subtask 1: Recruit subjects (10-11 per month)	6-36	40*
Subtask 2: Test subjects	6-36	40*
Subtask 3: Monitor recruitment and data collection	6-36	40*
Milestone(s) Achieved: 300 subjects recruited and tested; adjustments made to recruitment methods as needed	6-36	15*
<b>Major Task 3: Data analyses</b>		
Subtask 1: Quarterly interim data analyses on validation subjects to update prediction model	6-36	0*
Subtask 2: Annual report of prediction model and evaluation of test predictive utility	6-36	0*

\* Note: COVID-19 related delays. Further explanation regarding delays in % completion is provided in Section 5 Changes/Problems.

**What was accomplished under these goals?**

1) Major activities: In Y2, research staff sent over 630 recruitment letters and made over 2000 follow-up phone calls to Veterans previously identified as potential candidates through the pre-screening process. Of the 179 individuals screened over the phone, 77 were eligible for in-person screening. Participant testing began in Y2Q2. Efforts are ongoing to collect TCD data from currently enrolled participants. We have begun to analyze all other data collected from Y2. This has yielded a sample of individuals with varying self-reported hearing ability so that relationships between hearing ability and TCD can be explored.

2) Specific objectives: Continue to address Aims 1 and 2 through participant recruitment, enrollment and testing, and statistical model development.

3) Significant results: Subject testing began in Quarter 2. To date 42 individuals have been consented and 36 individuals (27 males) have enrolled in the study. We have scheduled ~ 115 and completed around 75 testing visits resulting in the following data set:

ABR	APD	LENS-Q	N-Back/ Corsi	OAE	Questionnaires	Stroop	TCD	WBR
24	30	21	0	23	36	20	0	33

The discrepancy between the number of scheduled and number of completed visits is due to participants cancelling, rescheduling, or not showing up for appointments. Please see the Changes/Problems section for more details.

Ultimately, Bayesian statistics will be used to predict deficits in outer hair cell (OHC) function, synaptic/neuronal function, central auditory processing, and working memory based on an individual's age and their performance on the TCD task.

4) Other achievements:  
Nothing to report.

Due to the COVID-19 pandemic, our research facilities were operating on limited status for all of Y2. This means that our ability to test individuals was restricted to approximately 6 days/month. In order to accommodate subjects' schedules and increase study visits, we set up a few Saturday clinics and added extra visits during the week as the facility schedule allowed. However, we continue to lag behind our original recruitment goals. Additional details may be found in Section 5 (Changes/Problems) of the report.

**What opportunities for training and professional development has the project provided?**

The project was not intended to provide training or professional development opportunities for the field in general.

**How were the results disseminated to communities of interest?**

Nothing to report.

**What do you plan to do during the next reporting period to accomplish the goals?**

We will continue with best efforts to recruit, enroll, and test Veteran participants and will analyze and report findings on all available data. Once we have collected sufficient data, we will begin to address how performance on the TCD test corresponds to Veterans' self-reported difficulties with hearing with statistical model development that investigates the relationship among indirect measures of outer hair cell (OHC) function (otoacoustic emissions), synaptic/neuronal function (auditory brainstem response and wideband acoustic reflexes), central auditory processing, and working memory (Stroop, N-Back, Corsi blocks) to determine speech processing ability.

**4. IMPACT:**

**What was the impact on the development of the principal discipline(s) of the project?**

The goal of this research is to develop a test of speech understanding that can be administered using mobile computing devices or remotely via the Internet. The development of a test of this kind will extend our ability to screen and diagnose hearing problems outside of a clinical setting and reduce the length and/or frequency of in-person clinical assessment and treatment.

**What was the impact on other disciplines?**

The findings of this project are likely to impact the health and well-being of the general population through the development of a test that can be used to screen and monitor the speech understanding of the aging population. Once the initial statistical model is developed, it can be evaluated and modified for application to older individuals with greater degrees of hearing loss.

**What was the impact on technology transfer?**

Many hearing aid companies are developing methods to estimate hearing ability remotely. The COVID-19 pandemic has highlighted the importance for telehealth and developing remote test measures.

**What was the impact on society beyond science and technology?**

Although many Service members with suprathreshold auditory dysfunction will experience little difficulty understanding speech in favorable communication situations, they will experience greater difficulty communicating in challenging listening environments such as in combat training or on the battlefield. It would be difficult to recreate a communication setting that is as complex and challenging as a real-life operational environment for the purposes of auditory testing. However, increasing the demands of listening tasks and simulating high-pressure communication situations can be achieved with the presentation of time-compressed signals.

Better methods of monitoring hearing changes in military service members that extend beyond pure tone thresholds are required so that auditory damage can be detected early, and appropriate preventative measures taken to minimize additional dysfunction. No forward operations screening for suprathreshold auditory function currently exists. A brief version of TCD test that could be used as a screener and a more comprehensive version that could serve as a differential diagnosis assessment could help assess whether a Service Member's hearing capability is sufficient to perform assignment duties.

Use of the test could be expanded to other environments where noise can severely impact speech understanding ability (e.g. hospital wards, manufacturing plants, etc) to help create a metric for when breaks need to be implemented or if certain pieces of noise-generating equipment need to be sound treated or re-engineered to reduce decibel output.

## **5. CHANGES/PROBLEMS:**

### **Changes in approach and reasons for change**

In order to decrease participant burden and consolidate the Lifetime Exposure to Noise and Solvents Questionnaire (LENS-Q) to better suit our study needs, we shortened the length and provided more detailed response options for the military noise exposure section.

### **Actual or anticipated problems or delays and actions or plans to resolve them**

Until April of 2020, Portland VA research was adhering to the CDC guidelines recommendation of only bringing in individuals who were not at higher risk for severe disease from COVID. In addition, in order to adhere to COVID guidelines on time-out periods and number of individuals in the facility, NCRAR had implemented a restricted patient testing schedule in which studies are only allowed to test individuals on pre-determined days.

While we were off to a good start at the beginning of Quarter 2, recruitment and enrollment efforts slowed during Quarter 3. However, Quarter 4 was more successful. In general, enrollment still proves to be more challenging across all studies at NCRAR. Several individuals have expressed hesitation at coming in for testing due to COVID-19. Out of those who have expressed interest and were scheduled for a screening visit, many cancel and reschedule appointments or do not show up for their appointments. In the past, we often posted flyers around local universities and attended Veteran outreach events. However, many of these avenues are no longer an option due to COVID. We will continue our recruitment efforts and try to brainstorm new ways to attract interested individuals.

While changes have not yet been implemented, we have begun to brainstorm changes in approach that may need to occur in order to mitigate any future slowdowns associated with COVID-19. This may include testing at community-based outreach centers, phone consenting, and/or tablet-based testing.

Because we are working with a younger participant population, we anticipate many individuals may cancel and reschedule appointments or not show up for their appointments. Participants in this age range tend to be part of the workforce or seeking employment, making it difficult for them to prioritize study participation. We plan on emphasizing our ability to complete multiple test sessions in one day to decrease the scheduling burden. We will also continue to offer the option of weekend and/or evening testing if warranted.

### **Changes that had a significant impact on expenditures**

Due to the delays in participant testing, we have not utilized all of the participant payment funds allocated for Year 2. In addition, certain supply and equipment purchases have been postponed due to reduced staff availability at our grant administration site (OHSU) and due to supply shortages.

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

**Significant changes in use or care of human subjects**

Nothing to report.

**Significant changes in use or care of vertebrate animals**

N/A

**Significant changes in use of biohazards and/or select agents**

N/A

**6. PRODUCTS:**

- **Publications, conference papers, and presentations**

**Journal publications.**

Nothing to report.

**Books or other non-periodical, one-time publications.**

Nothing to report.

**Other publications, conference papers and presentations.**

Nothing to report.

- **Website(s) or other Internet site(s)**

Nothing to report.

- **Technologies or techniques**

Nothing to report.

- **Inventions, patent applications, and/or licenses**

Nothing to report.

- **Other Products**

Nothing to report.

## **7. PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS**

**What individuals have worked on the project?**

Name: Michelle Molis  
Project Role: Principal Investigator  
Researcher Identifier (e.g. ORCID ID): n/a  
Nearest person month worked: 6.4  
Study contribution: Dr. Molis has aided in the development in a Python-based version of the TCD program.

Name: Serena Dann  
Project Role: Research Audiologist  
Researcher Identifier (e.g. ORCID ID): n/a  
Nearest person month worked: 7.2  
Study contribution: In addition to the continuation of work completed in previous quarters, Dr. Dann has completed work in the areas of participant recruitment and enrollment, data collection, organization and analysis.

Name: Melissa Frederick  
Project Role: Research Audiologist  
Researcher Identifier (e.g. ORCID ID): n/a  
Nearest person month worked: 4  
Study contribution: Dr. Frederick has completed work in the areas of participant recruitment and enrollment, data collection, organization and analysis.

Name: Naomi Bramhall  
Project Role: Co-Investigator  
Researcher Identifier (e.g. ORCID ID): n/a  
Nearest person month worked: 1.2 (no charge to grant)  
Study contribution: Dr. Bramhall has aided in the development in a Python-based version of the ABR scoring program used to analyze study ABR data.

Name: Melissa Papesh  
Project Role: Co-Investigator  
Researcher Identifier (e.g. ORCID ID): n/a  
Nearest person month worked: 1.2 (no charge to grant)  
Study contribution: Dr. Papesh has aided in the development in a Python-based version of the TCD program.

Name: Gregory Sebastian  
Project Role: Research Assistant  
Researcher Identifier (e.g. ORCID ID): n/a  
Nearest person month worked: 12  
Study contribution: Mr. Sebastian assisted in participant recruitment and scheduling.

Name:	Garnett McMillan
Project Role:	Biostatistician
Researcher Identifier (e.g. ORCID ID):	n/a
Nearest person month worked:	1.8
Study contribution:	no change

Name:	Samuel Gordon
Project Role:	Engineer
Researcher Identifier (e.g. ORCID ID):	n/a
Nearest person month worked:	1.8
Study contribution:	no change

**Has there been a change in the active other support of the PD/PI(s) or senior/key personnel since the last reporting period?**

Nothing to report.
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**What other organizations were involved as partners?**

Organization Name: Oregon Health Sciences University (OHSU)

Location of Organization: Portland, Oregon

Partner's contribution to the project:

- Financial distribution
- Purchasing
- Grant administration
- Joint IRB oversight with VA Portland HCS

## **8. SPECIAL REPORTING REQUIREMENTS**

**COLLABORATIVE AWARDS:**

**QUAD CHARTS:**

## **9. APPENDICES:**