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TITLE: Rapid, Multileveled Assessment of Hearing Dysfunction in Operational and Postdeployment Environments

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<b>14. ABSTRACT</b> Fitness-for-duty requires good hearing and speech communication ability, especially in complex and noisy environments. But despite its crucial role in operational performance, medical and support personnel have no means to rapidly and reliably assess the integrated functioning of the auditory-speech processing system, either in the clinic or in forward remote settings. Furthermore after deployment, over a million Veterans with Service-related hearing disability – many of whom are older as well – struggle to understand speech in noisy environments such as work meetings or family gatherings, leading to a cascade of physical and mental/emotional health decline. However, because auditory dysfunctions are complex and multi-leveled they remain largely “hidden” audilogically. Measures using simple sounds and detection-threshold tasks, which inform the present US Army H1-H4 fitness-for-duty profile, fail to predict speech comprehension and job performance in Service members. For this profound military operational need, no assessment tool exists. This research will validate a powerful new EEG diagnostic – applicable in austere deployed settings – to assess auditory dysfunction as related to hidden hearing loss and central auditory processing disorders (US Patent No. 10,729,387). Our rapid (5-10min) brain-behavior assessment of listening uses continuous, uniquely engineered speech to differentiate multiple levels of dysfunction from the auditory periphery to cognition, including how these levels interact. This will enable quick screening of Service members in the field for auditory combat-readiness.					
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1. **INTRODUCTION:**

Fitness-for-duty requires good hearing and speech communication ability, especially in complex and noisy environments. But despite its crucial role in operational performance, medical and support personnel have no means to rapidly and reliably assess the integrated functioning of the auditory-speech processing system, either in the clinic or in forward remote settings.

Furthermore after deployment, over a million Veterans with Service-related hearing disability – many of whom are older as well – struggle to understand speech in noisy environments such as work meetings or family gatherings, leading to a cascade of physical and mental/emotional health decline. However, because auditory dysfunctions are complex and multi-leveled they remain largely “hidden” audiologically. Measures using simple sounds and detection-threshold tasks, which inform the present US Army H1-H4 fitness-for-duty profile, fail to predict speech comprehension and job performance in Service members. For this profound military operational need, no assessment tool exists. This research will validate a powerful new EEG diagnostic – applicable in austere deployed settings – to assess auditory dysfunction as related to hidden hearing loss and central auditory processing disorders (US Patent No. 10,729,387). Our rapid (5-10min) brain-behavior assessment of listening uses continuous, uniquely engineered speech to differentiate multiple levels of dysfunction from the auditory periphery to cognition, including how these levels interact. This will enable quick screening of Service members in the field for auditory combat-readiness. Our Specific Aims include: AIM 1: Relate objective measures of hearing ability – from the brainstem through cognition – to relevant behavioral measures of operational performance (comprehension, ignoring distractions) and readiness (listening fatigue). AIM 2: Establish the test-retest reliability of the measures, within individual listeners over time (months to years). This will enable an “Early Warning” system to detect any decline in listening ability. AIM 3: Demonstrate that non-specialists can use the test to classify fitness-for-duty with durable, off-the-shelf hardware and minimal training in noisy or remote environments.

2. **KEYWORDS:**

hearing loss, speech perception, auditory dysfunction, fitness-for-duty, selective attention, audiology, electroencephalography, EEG, auditory brainstem response, ABR, speech tracking

3. **ACCOMPLISHMENTS:**

o **What were the major goals of the project?**

The major goals that overlap with this period of the project are shown below. As noted in our prior report, all human subjects-related goals were severely impacted by the COVID-19 research shutdown extending from the first project period into the prior period (winter 2022). We are pleased to report that we are now operating at full capacity, with no Covid-related restrictions. We have also recently resolved a clinical bottleneck in participant throughput (see below), thereby increasing our capacity to gather data by a factor of three. We are therefore proceeding rapidly with the remaining data collection and all project goals.

	<b>Proposed Timeline</b>	<b>Completion Date</b>	<b>% Complete</b>
<b>Specific AIM 1: Performance-based neurobehavioral fitness-for-duty classifier</b>	Months		
Pilot EEG-task sessions	4-5	2/2023 Study complete with <b>31 Civilians enrolled;</b> manuscript in preparation	100%
Audiological Exams (Veterans)	6-24	Actively running: <b>34 Veterans enrolled</b>	50%
Behavioral and EEG-task sessions (Veterans)	6-24	Actively running: <b>34 Veterans enrolled</b>	50%
Establish licensing agreements and industry partnerships	18-36	Actively engaged: Interacoustics	40%
<b>Specific AIM 2: Test-retest reliability and “Early Warning” profile</b>			
Audiological Exams, sessions 2-4	2-30	Actively running; Recruitment and scheduling for test-retest underway	20%
Behavior and EEG-tasks, sessions 2-4	2-30	Actively running; Recruitment and	20%

		scheduling for test-retest underway	
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<b>Specific AIM 3: Non-specialist use in austere environment</b>			
Software development: automated processing framework and intuitive GUI interface	25-27	Refining code base for ease-of-use	80%
Non-specialist testers administer fitness-for-duty classifier with durable, off-the-shelf hardware and minimal training, in austere environment	27-32	Testing and standardizing minimal training regimen with volunteers (n=6)	30%

○ **What was accomplished under these goals?**

***Major activities and significant results***

In this award period, we achieved significant progress on all project goals including completing data acquisition for the entire civilian cohort (n=31 enrolled), which serves as the baseline for training our auditory fitness-for-duty classifier. We also made significant progress on gathering data from our Veteran cohort (n=34 enrolled, age 23-64). This has been enabled by a team dedicated solely to recruitment, which ensures that we reach a broad range of age and hearing status and includes outreach efforts through the Sacramento Veterans Administration Health Center, UC Davis Veterans Success Center, the Sacramento State University Veterans Success Center, VFW posts, Facebook groups, and UC Davis Health Center. Finally, we are actively communicating with industry partners (e.g. Interacoustics, the premier manufacturer of audiological diagnostic equipment) with the aim of identifying a licensee for our approach. We have presented our data at international conferences and now have **four** manuscripts in preparation describing our powerful methodological approach and results.

Below is a review of the experimental sessions we have been running and a conceptual framework for our analysis pipeline as it is now implemented. Following that, examples of our significant results from the reporting period show reliable, neuro-behavioral signatures at multiple levels of speech processing in our challenging, dynamic task.

We are now enrolling the remaining Veteran participants, all of whom complete the following three visits: 1) Audiological exam, 2) Behavioral visit, 3) Experimental (behavior-EEG) task. The audiological exam provides a clinically standard assessment of hearing health and dysfunction, in addition to several measures not always acquired clinically but that have particular relevance for “hidden” hearing loss, including extended high frequency (EHF) audiometry and otoacoustic emissions. Our clinical partners at the UC Davis Audiology Clinic have been extremely helpful in implementing our paradigm and scheduling participants, despite some challenges with equipment and staffing that we have now resolved. Visit 2 comprises a battery of perceptual and cognitive tests that are likely predictive of speech perception in realistic

environments. Some of these are low level perceptual tests, as for temporal fine structure (fast changes in sound), while others are cognitive (working memory) or reflect hearing history (noise exposure). Finally Visit 3 consists of the EEG and pupillometry recordings while subjects perform the challenging, dynamic listening task. Subjects must switch their attention and gaze between two simultaneous talkers in two different spatial locations in order to understand a narrative and identify target words. This is where we use our patented engineered speech EEG approach to differentiate multiple levels of dysfunction from the auditory periphery to cognition.

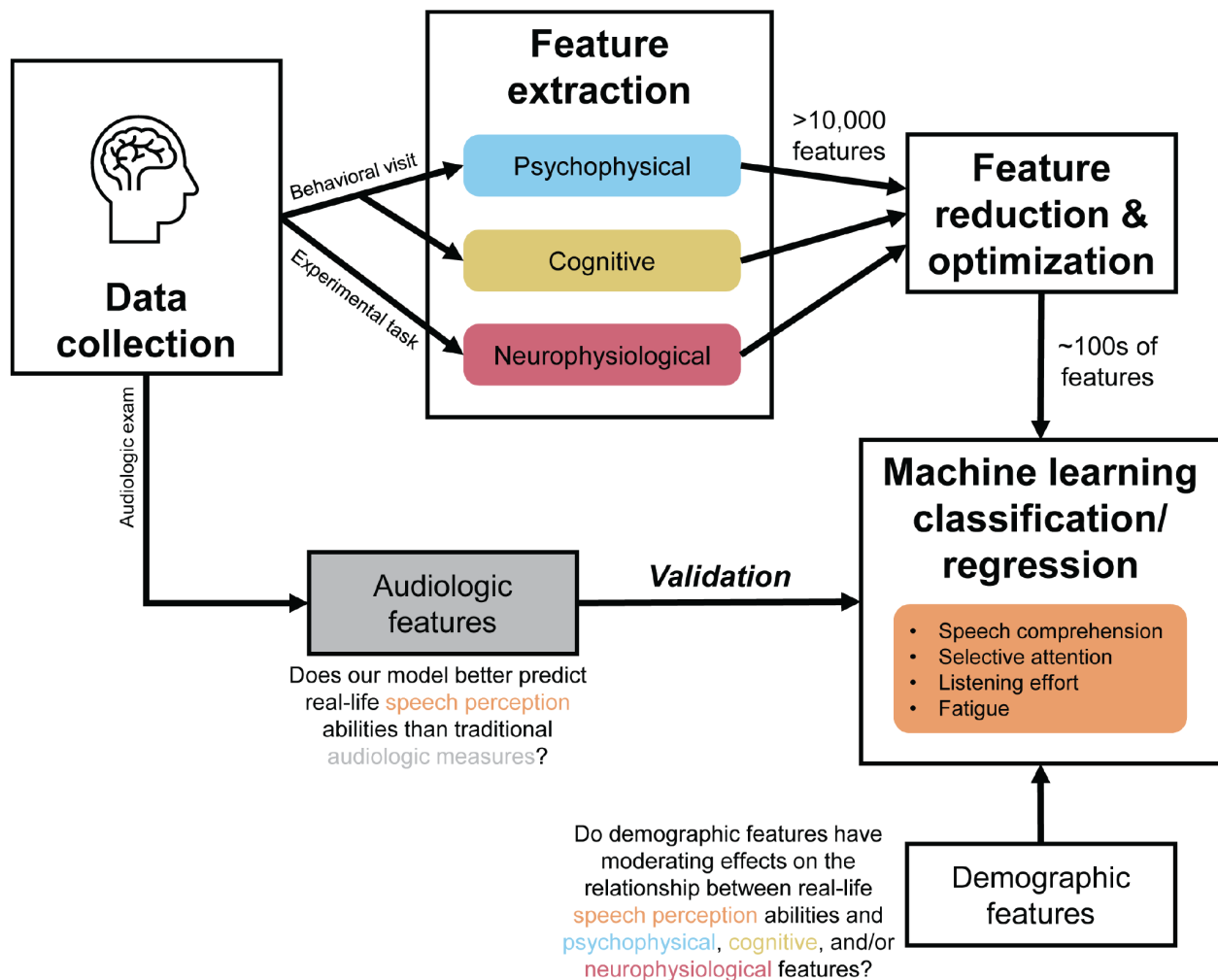
<b>Visit day</b> <i>Location</i>	<b>Visit 1: Audiologic Exam</b> <i>UC Davis Otolaryngology and Audiology Clinic</i>	<b>Visit 2: Behavioral Visit</b> <i>UC Davis Center for Mind and Brain</i>	<b>Visit 3: Experimental Task</b> <i>UC Davis Center for Mind and Brain</i>
<b>Purpose of visit</b>	Provide clinically standard assessment of hearing health & dysfunction	Evaluate individual performance on relevant (but not clinically standard) perceptual and cognitive factors relevant for speech perception	Obtain neuro-behavioral metrics of naturalistic speech listening performance
<b>Specific measures per visit</b>	<b>Tests performed by a professional audiologist:</b> <ul style="list-style-type: none"> <li>• Pure tone audiometry (+ EHF)</li> <li>• Word recognition</li> <li>• Otoscopy</li> <li>• Tympanometry</li> <li>• Acoustic reflexes</li> <li>• Distortion product otoacoustic emissions</li> <li>• QuickSIN</li> </ul>	<b>Psychophysical (auditory) factors:</b> <ul style="list-style-type: none"> <li>• Speech-in-noise perception*</li> <li>• Temporal fine structure</li> <li>• Pitch discrimination</li> </ul> <i>*includes QuickSIN from visit 1</i>	<b>Neurophysiological factors:</b> <ul style="list-style-type: none"> <li>• Neural encoding from brainstem→cortex</li> </ul>
		<b>Cognitive factors:</b> <ul style="list-style-type: none"> <li>• Working memory</li> <li>• Processing speed</li> <li>• Executive control</li> <li>• Inhibitory control</li> </ul>	<b>Objective &amp; subjective measures of speech listening performance:</b> <ul style="list-style-type: none"> <li>• Speech comprehension</li> <li>• Selective attention</li> <li>• Listening effort</li> <li>• Fatigue</li> </ul>
		<b>Self-report hearing questionnaires:</b> <ul style="list-style-type: none"> <li>• Lifetime noise exposure</li> <li>• Subjective daily life hearing abilities</li> </ul>	

Specific measures from each of these visits – most importantly the neurobehavioral metrics from Visit 3 – will determine which tests or factors best predict objective and subjective naturalistic speech listening performance in Veterans (orange box, bottom right) and will drive the auditory fitness-for-duty classification. These performance measures include:

- Speech comprehension: accuracy on target narrative comprehension questions at the end of each block
- Selective attention: target word hit rate (identification accuracy for color words embedded in narrative) & gaze-shift accuracy to the cued target speech location
- Objective listening effort: pupil dilation responses
- Speech tracking fatigue: reaction times of target word identification & cued gaze-shift
- Subjective listening effort & general fatigue: self-report ratings

The three visits yield a large number of metrics or features (>10,000) – practically too many for a fitness-for-duty classifier to operate on. We are therefore winnowing features of interest using a feature reduction/optimization process. In the prior funding period, we had begun work on a deep neural network architecture that has recently shown great promise for this application, known as an autoencoder. We have now complemented the autoencoder with a powerful linear,

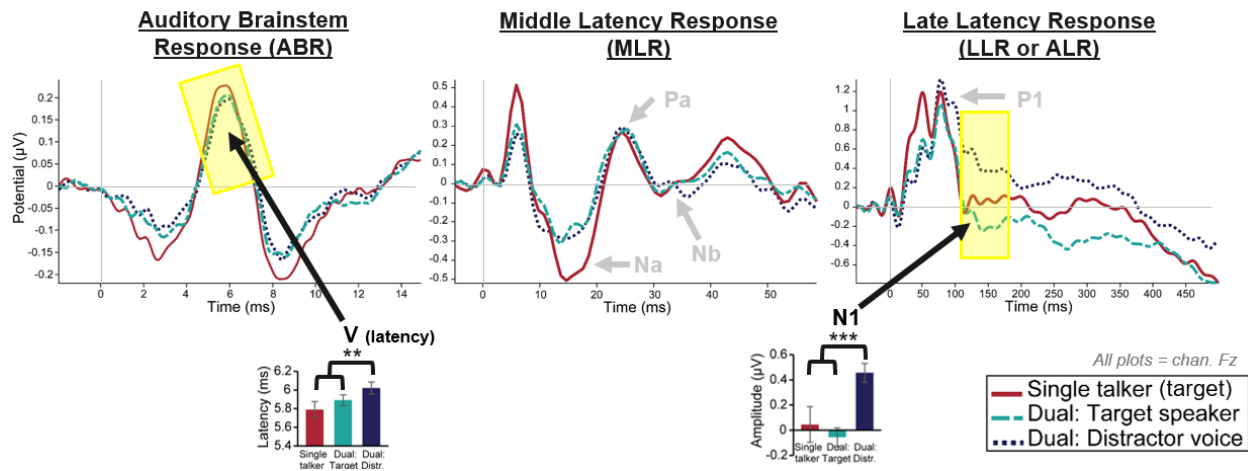
multivariate technique called Partial Least Squares (PLS). In contrast to autoencoders, which offer extreme data reduction but can lack linear, readily interpretable output, PLS explicitly identifies patterns of brain activity and behavior (e.g. speech comprehension) that maximally share variance in the form of “profiles”. These two techniques therefore complement one another and empower our classification efforts. Finally, a machine learning algorithm (e.g. Support Vector Machine) will then characterize neurobehavioral profiles on this reduced feature set to distinguish good versus poor speech listeners. Demographic features (e.g., age; SES) will be evaluated as potential moderating variables. These results will be validated against traditional audiologic measures to predict real-life speech perception performance.



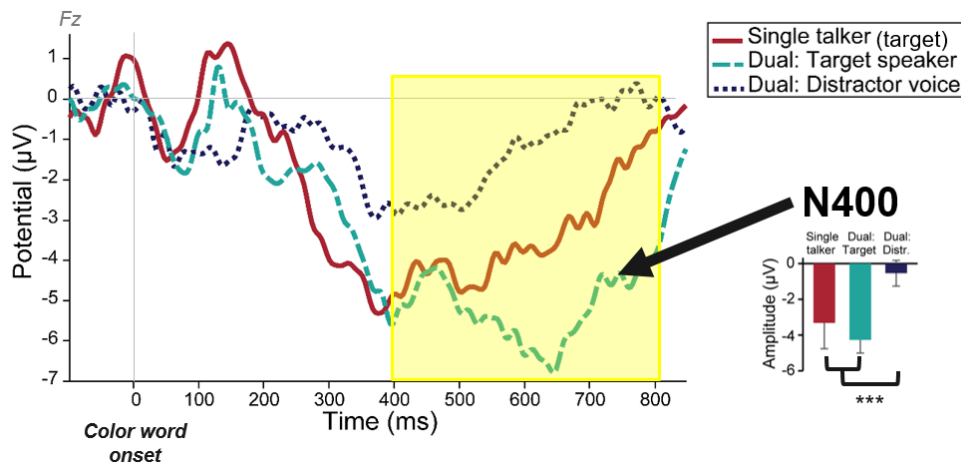
In our prior report period, we demonstrated that we could obtain high-quality speech neurophysiological data using our patented approach. This includes EEG data depicting neural processing at multiple levels of the auditory pathway, simultaneously during continuous, naturalistic speech listening: Auditory brainstem (ABR), middle latency (MLR), and late latency responses (LLR) to the engineered speech. The ABR waves reflect how well speech sound is first encoded in the brain after it enters the ear. In older listeners with hearing loss, we expect the

fidelity of this signal to degrade. The MLR waves reflect how well the speech is transmitted from low levels to higher levels in the auditory brain. The LLR reflects how the speech is processed in auditory cortex and further stages – those that determine speech meaning, attention, etc. Our results from this reporting period show numerous neuro-behavioral metrics indicative of successful for failed listening ability. These are the metrics we are incorporating into our fitness-for-duty classifier.

Below we highlight some results from the completed civilian cohort. First, when we test the effects of selectively attending to speech, i.e. brain responses to target (attended) speech versus distractor speech, we observe that attended speech is processed with faster peak latencies as early as wave V of the ABR. Interestingly, we again observe attention-related effects in the later N1 amplitudes—smaller, more positive N1s for distractor relative to target story responses.



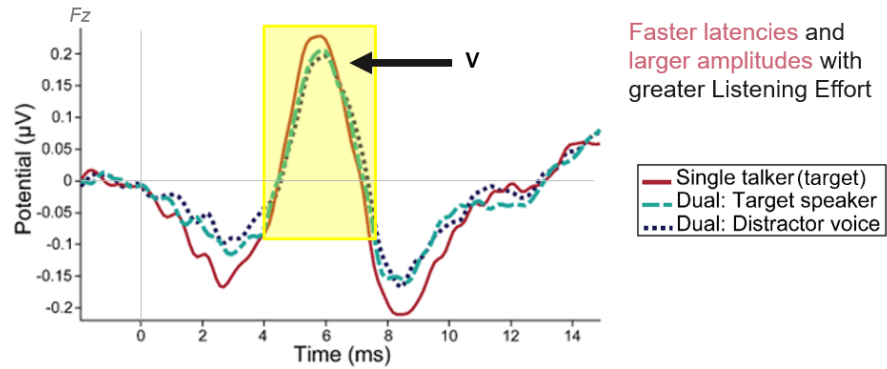
These results suggest that an interaction between higher order cognitive processes like attention and early sensory encoding is critical for successful listening. This is precisely the sort of interaction that would be missed with typical approaches. Rather, our technique gives a real-time, synoptic view of all levels simultaneously.



Still later in cortical processing, we observe N400 responses, which reflect the brain’s “online” efforts to integrate linguistic information such as word meaning. Here we see robust N400 responses to target

color words in the single talker condition and the target narrative, but we do not see a response to target words in the distractor narrative. *This demonstrates clearly that our classifier will have the ability to identify listeners whose brains fail to suppress distracting linguistic information – a crucial ability in operational environments.*

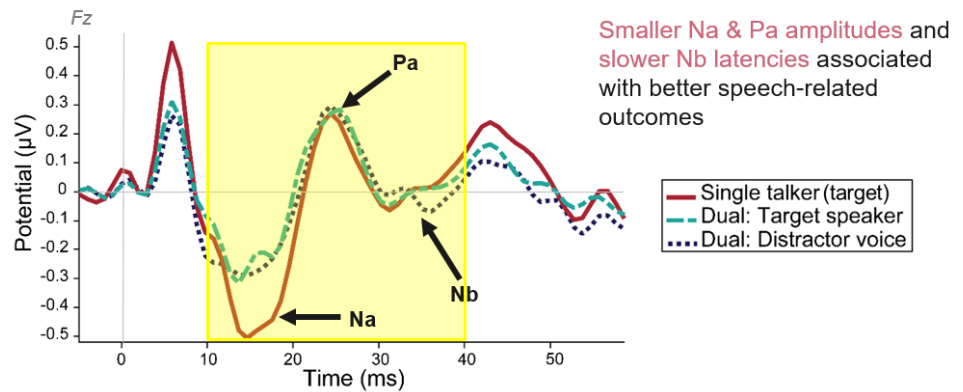
Further evidence from the earliest neural responses demonstrates that encoding at the brainstem level (ABR) correlates with high-level speech-related behaviors such as ratings of listening effort. In particular, faster wave V latencies were associated with better



Faster latencies and larger amplitudes with greater Listening Effort

selective attention and larger wave V amplitudes corresponded with reduced ratings of listening effort. This remarkable association gives us confidence that our neuro-behavioral profiles are capturing not just differences in neural activity, but differences in neural activity that *matter* for listening experience and success.

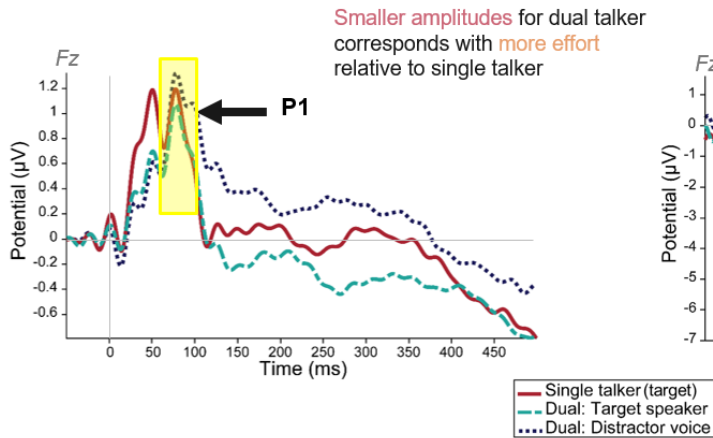
Similarly, our rich assessments of speech-related behavioral metrics can be identified as speech information ascends through the auditory hierarchy. Here we show in the MLR that better speech listening performance is associated with smaller Na & Pa amplitudes and slower Nb latencies. This suggests is that these thalamo-cortical pathways



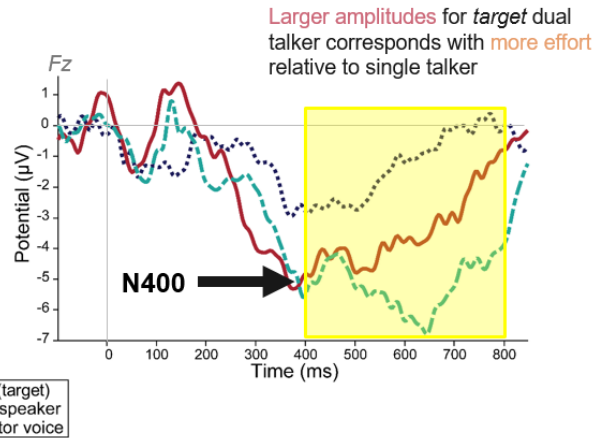
Smaller Na & Pa amplitudes and slower Nb latencies associated with better speech-related outcomes

which generate the MLR reflect whether or not speech information reaches higher levels of processing in auditory cortex.

## Late latency response (LLR or ALR)



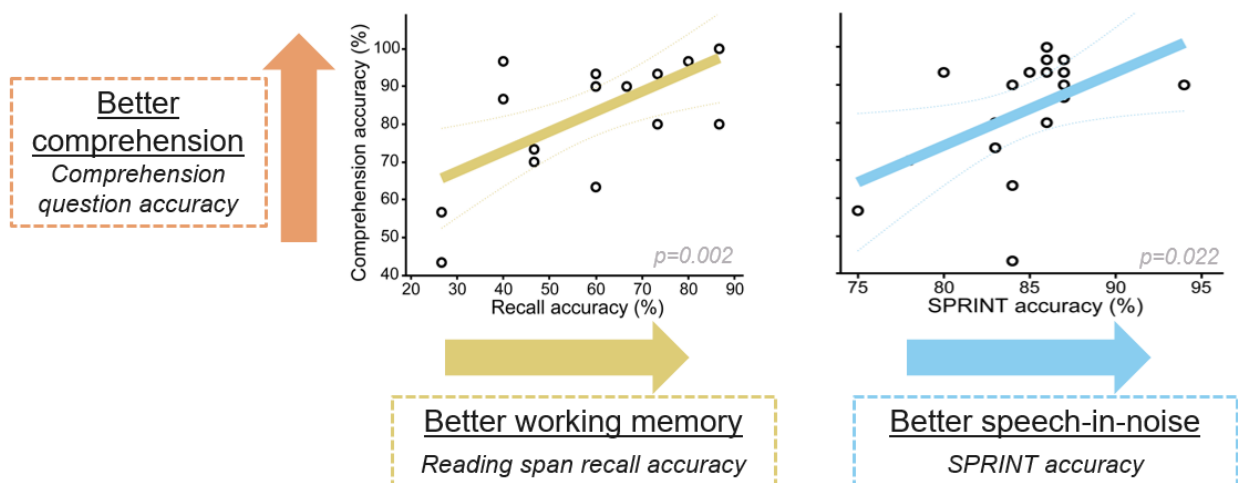
## N400



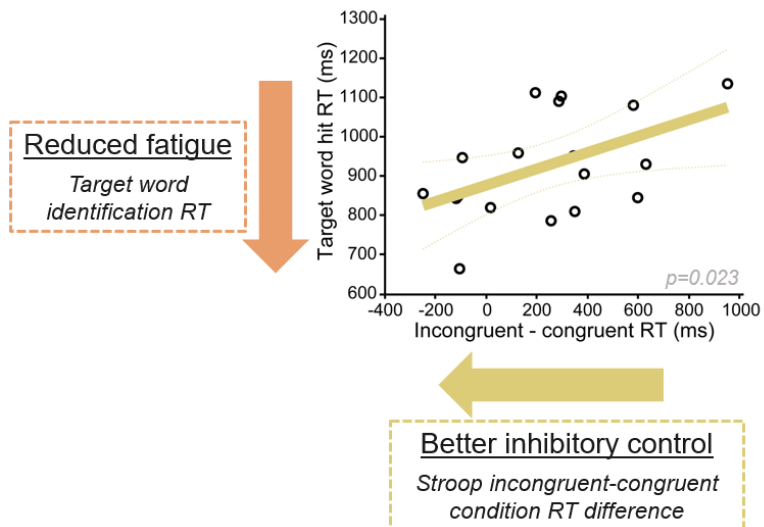
Finally, listening effort was also highly related to the late cortical potentials—smaller P1 amplitudes of the LLR and larger N400 amplitudes for the dual talker conditions were associated with higher ratings of listening effort relative to the single talker.

Collectively, our results demonstrate a key role for early ascending pathways to process and hone the incoming signal, but the cortex must further isolate and refine speech-related information and drive subsequent performance, including comprehension and perceived listening effort.

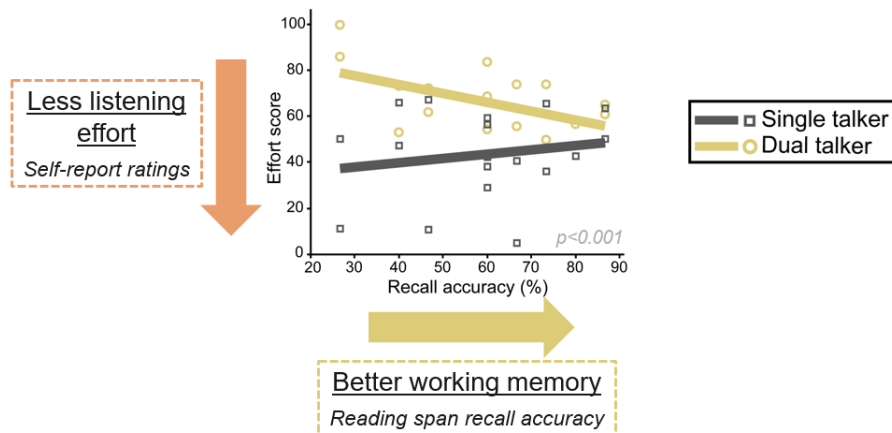
In addition to the electrophysiological results, we have also begun to identify illustrative associations among the many cognitive-behavioral measures that we collect in all subjects. For instance we can show clearly that comprehension accuracy is associated with both working memory and speech in noise (SPRINT) test performance.



Additionally, reduced fatigue (specifically faster target word identification RTs) was related to inhibitory control as measured by a color Stroop task. Note that the Stroop task is a cognitive test having nothing *prima facie* to do with auditory ability or speech-in-noise – yet it shows a strong association, indicating that our realistic task loads heavily on inhibitory control.



Finally, working memory also played a role in listening effort; specifically, better working memory was associated with reduced listening effort difference between the dual talker versus single talker condition.



Overall, we are excited and emboldened by these results, as they demonstrate high sensitivity to exactly the kinds of neural features that will distinguish good from poor listeners in our classifier. They also demonstrate how speech perception relies on numerous *general cognitive abilities* as well as speech and language specific processing. With our novel and comprehensive neuro-cognitive-behavioral approach, we can – for the first time – leverage these related mechanisms to rapidly diagnose and characterize listening success in an individual.

*Stated goals not met:* Goals not met are enumerated in the SOW chart above and are strictly limited to those impacted by the prior period’s COVID-19 research shutdown.

- **What opportunities for training and professional development has the project provided?**  
The project is not primarily framed as a training and professional development opportunity, however research of this kind inevitably serves that purpose – particularly for junior researchers. During this reporting period, both our postdoctoral scholars completed multiple professional and

technical training opportunities such as *ERP Decoding for Everyone: Center for Mind and Brain, University of California Davis (7/2023)* and *Cognition and Natural Sensory Processing online Workshop* (advanced methodologies for neural signal processing for natural scenes and sound perception) (7/2022).

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

We presented our research to numerous regional, national, and international audiences, both academic and in industry. These are listed below under “conference papers and presentations”.

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

We have all necessary project personnel on board and working productively. All the logistics of subject recruitment, clinical assessment, and experimentation are running smoothly. We are on track to 1) complete data collection for remaining Veteran participants; 2) test our classifier; 3) complete test-retest reliability and demonstrate approach in austere environment; 4) establish licensing agreements; and 5) submit manuscripts for publication

#### 4. **IMPACT:**

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

This research is likely to significantly advance toward clinical/field application the first and only auditory fitness-for-duty assessment that validates operational performance and readiness for active-duty Service members. This novel assessment tool will have immediate, profound impact on Service member team safety, communication, and effectiveness in dynamic and noisy environments.

Our listening diagnostic builds on years of careful research by our lab and many others, but real world impact depends as much on practical implementation as it does on the underlying science: if an auditory fitness-for-duty assessment can only be conducted in a large hospital or laboratory by highly trained personnel, its impact will be sorely limited. Our approach is uniquely designed from the outset for the broadest possible application, through its speed, portability, robustness in austere or adverse environments, and ease of use by non-specialists. Our proposed research will validate all these attributes, demonstrating that inexperienced individuals with only one hour of training can conduct the assessment rapidly and reliably.

The method is equally applicable in post-deployment Veterans, many of whom suffer from lasting service-related auditory injury. Here, the method’s speed and ease of use will also impact its utility, bringing the tool within reach not only of large VA hospitals but also small private audiology practices and local, non-specialized clinics.

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

Beyond the operational and post-deployment impact on military personnel and their families, in the long term our approach has the potential to transform restorative hearing health care globally, ultimately improving care for the half a billion people worldwide who have hearing loss. Every day these individuals struggle to understand speech, particularly in noisy conditions, leading to billions of dollars in lost productivity (in the US alone, hundreds of billions annually) and, too

often, a tragic and costly cascade of social, psychological, and physical decline. The challenge is that a listener's difficulty understanding speech in real life stems not only from problems in the ear, but from how each individual's brain processes sounds. For decades, our capable audiology providers and hearing device manufacturers have struggled to enact effective, individualized hearing care because they lack the means to rapidly and reliably assess the integrated functioning of the auditory system in a life-relevant context. As a result, they are limited in how to guide treatment. For instance hearing aids and other devices are often poorly matched to an individual's impairment, and aids often fail in the situations where listeners need them most: e.g. restaurants, business meetings, family gatherings. Moreover, nascent cellular and molecular treatments for hearing loss (e.g. hair cell restorative drugs) also lack an objective, multileveled metric of therapeutic impact. For this profound global health problem and frank scientific-industrial need, no clinical assessment tool has ever existed. Our ongoing research will finally provide it.

- **What was the impact on technology transfer?**  
Granting of the core patent underlying our approach in the prior period (8/4/2020) represented a significant step toward technology transfer. We expect this technology to have a commercial impact, either through a startup and/or licensing agreements. As we obtain the remaining human subjects data in Y23-24, our Office of Research will prepare a regulatory approach with UC Davis Tech Transfer office, including any premarket applications to the FDA, will help apply for funding to conduct any anticipated trials necessary for classification and clearance, and will contact additional potential industry partners. To this end, we are in contact with potential licensees of our approach (e.g. Interacoustics).
- **What was the impact on society beyond science and technology?**  
The work is likely to have a substantial impact on society and employment by improving the audiological treatment, social integration, and work productivity of those with hearing loss. Since hearing loss leads to a cascade of mental and physical impairments (social isolation, depression), the research promises to ameliorate many of these costly downstream effects as well.

## 5. CHANGES/PROBLEMS:

- **Changes in approach and reasons for change**  
Nothing to Report.
- **Actual or anticipated problems or delays and actions or plans to resolve them**  
As described above, all our participants must undergo standard audiological exams, which have heretofore been conducted by our excellent team at the UC Davis Audiology Clinic. However since late 2022, our clinic has been experiencing an overwhelming load from the community, so our pace of exams for Veteran participants had become severely limited by available appointments. Furthermore, the clinic lost several full-time audiologists, with no immediate prospect of replacement. UC Davis had no other clinics that could fill our research need. We have therefore pivoted to conduct the majority of remaining audiological exams in the Miller laboratory. The lab possesses a dual-wall, acoustically shielded chamber that exceeds audiological standards. We have an industry-leading Inventis Cello audiometer with high-

frequency capability (as required for this study), which we have validated against audiometers in the Clinic. And we have now acquired an Interacoustics Titan V4 Clinical Middle Ear Analyzer/ DPOAE/ TEOAE/ WBT to complete the necessary exam tests. We are therefore no longer constrained by clinical scheduling challenges, and our participant throughput has tripled. Further enabled by our Extension Without Funds approved for '23-24, we anticipate completion of data collection from the Aim 1 Veteran cohort by 1/2024.

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

In the prior period, the COVID-19 research shutdown had led to a temporary reduction in expenditures, in particular delays in hiring staff and human subjects costs (subject payments, audiological exams). In the present reporting period, we have now been running at full capacity and expected expenditures.

- **Significant changes in use or care of human subjects, vertebrate animals, biohazards, and/or select agents:** None.

- **Significant changes in use or care of human subjects:** None

- **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.**

- In preparation: Mankel K, Comstock DC, Abou Najm K, Bormann B, Sagiv D, Brodie H, Miller LM. *The role of auditory, neural, and cognitive factors in detecting hidden hearing loss on a novel speech comprehension task.*

Acknowledgment of federal support: **Yes**

- In preparation: Comstock, DC, Mankel K, Miller LM. *A multiscale approach to assessing neural mechanisms of speech processing.*

Acknowledgment of federal support: **Yes**

- In preparation: Bormann B, Mankel K, Comstock D, Das S, Sagiv D, Brodie H, Miller LM. *Effects of selective attention on speech encoding in the brainstem, thalamus, and cortex.*

Acknowledgment of federal support: **Yes**

- In preparation: Statema T, Das S, Bormann B, Mankel K, Comstock D, Sagiv D, Brodie H, Miller LM. *History of noise exposure predicts cortical speech processing fidelity in Veteran listeners.*

Acknowledgment of federal support: **Yes**

- **Books or other non-periodical, one-time publications.** Nothing to Report.

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

- Mankel, K., Comstock, D. C., Bormann, B., Sagiv, D., Brodie, H., Miller, L.M., *Hierarchical neural organization in the auditory brain revealed during naturalistic speech listening by a dynamic, spatial attention task*. Oral Presentation at the 46th Annual MidWinter Meeting of the Association for Research in Otolaryngology (2/2023)
- Comstock DC, Miller LM, *Brain-Based Approaches for Hearing-Loss Diagnostics and Treatments*. Oral Presentation at the Research Seminar Series at Accenture Labs, San Francisco, CA (3/2023)
- McKie J, Chan C, Bormann B, Mankel K, Comstock D, Miller LM. *An EEG Investigation to Evaluate Multi-Level Processing of Language in Ecologically Relevant Conditions*. UC Davis Undergraduate Research Conference (4/2023)
- Comstock D. C. *A Multilevel Approach to Extracting Neural Markers of Hearing Loss and Speech Processing*. Oral Presentation at the Center for Mind and Brain EEG Seminar Series, University of California Davis (6/2023)
- Additionally, Professor Miller delivered Invited Presentations describing our ongoing work at several forums including the UC Davis Dept. Otolaryngology / Head & Neck Surgery Annual Research Symposium and the UC Davis Center for Neuroengineering and Medicine. These presentations were attended by local and regional researchers and clinicians, as well as university administrators and Office of Research staff.

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

We anticipate study data to be disseminated to the scientific community in concert with several publications in preparation, beginning in the first quarter of 2024.

○ **Technologies or techniques**

We continue to refine the machine learning model that will serve as the core of our auditory fitness-for-duty classifier (see section *Accomplishments* for details). We will make all Research Resources publicly available in accordance with CDMRP expectations, as expressed in the General Application Instructions, Appendix 2, Section K.

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

None in the present reporting period.

○ **Other Products**

Our novel behavioral-EEG paradigm and the EEG data analysis pipeline are complete, and our machine learning classifier is under active development.

**7. PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS**

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

Name:	Lee M. Miller
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Project Role, etc.:	PI (no change)
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Name:	Hilary Brodie
Project Role, etc.:	co-PI (no change)

Name:	Kelsey Mankel
Project Role:	Postdoc
Researcher Identifier (ORCID ID):	0000-0002-6953-4778
Nearest person month worked:	12
Contribution to Project:	Dr. Mankel is lead postdoc on the audiological and auditory cognitive aspects of the project
Funding Support:	No funding outside this award.

Name:	Daniel Comstock
Project Role:	Postdoc
Researcher Identifier (ORCID ID):	0000-0001-5861-0838
Nearest person month worked:	12
Contribution to Project:	Dr. Comstock is lead postdoc on the EEG analysis and machine learning aspects of the project
Funding Support:	No funding outside this award.

Name:	Brett Bormann
Project Role:	graduate student
Researcher Identifier (ORCID ID):	none

Nearest person month worked:	6
Contribution to Project:	Mr. Bormann worked to develop the behavioral-EEG task; recruit and collect data from civilian and Veteran participants;
Funding Support:	Remaining funding during the academic Y22-23 was provided through a Teaching Assistantship

Name:	Soukhin Das
Project Role:	graduate student
Researcher Identifier (ORCID ID):	0000-0001-8792-4406
Nearest person month worked:	3
Contribution to Project:	Mr. Das recruited and collect data from civilian and Veteran participants;
Funding Support:	Remaining funding during the academic Y22-23 was provided through a Teaching Assistantship

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

No

- **What other organizations were involved as partners?**

Nothing to Report

8. SPECIAL REPORTING REQUIREMENTS

o QUAD CHART:

o

Rapid, Multileveled Assessment of Hearing Dysfunction in Operational and Post-deployment Environments



Log #: RH190061  
Award # W81XWH2010485  
PI: Miller, Lee M

Org: University of California, Davis Award Amount: \$1,530,179

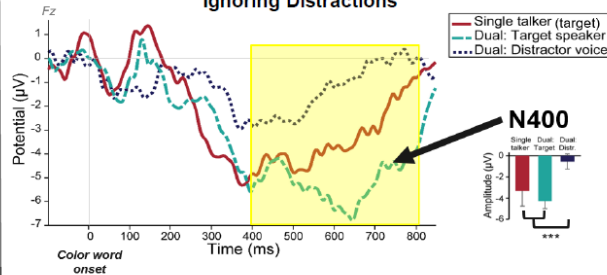
**Project Aims**

1. Relate brain-based measures of hearing ability to operational performance (comprehension, ignoring distractions) and readiness (listening fatigue).
2. Establish test-retest reliability of the measures within individual listeners over time (months to years). This will enable an "Early Warning" system to detect any decline in listening ability.
3. Demonstrate that non-specialists can use the automated test to classify auditory fitness-for-duty with durable, off-the-shelf hardware and minimal training, in noisy or remote environments.

**Approach**

A rapid (5-10min) brain-behavior assessment of listening uses continuous, uniquely engineered speech and EEG to differentiate multiple levels of dysfunction from the auditory periphery to cognition (US Patent #10,729,387). This will enable quick screening of Service members in the field for auditory combat-readiness.

**Brain biomarkers of successful speech comprehension: Ignoring Distractions**



Accomplishments: We are training our fitness-for-duty classifier on neurobehavioral features that signal listening performance, e.g. how the brain evaluates word meanings (N400). This biomarker clearly distinguishes when a listener can successfully ignore distractions.

**Timeline and Cost**

Activities	Year	20-21	21-22	22-23	EWf
Develop Machine Learning Classifier		█	█	█	█
Behavior-EEG and Audiological Exams			█	█	█
Test / Retest Reliability (sessions 2-4)					█
Non-specialist testers administer fitness-for-duty classifier				█	█
<b>Estimated Budget (\$K)</b>		<b>\$235k</b>	<b>\$350k</b>	<b>\$569k</b>	<b>\$375k</b>

Updated: 29 July, 2023

**GOALS / MILESTONES**

**Y20-21 Milestones – Experimental and Software Development**

- ☑ Awarded US Patent for approach (No. 10,729,387, 4 Aug., 2020)
- ☑ Published in high-profile journal (J Cognitive Neuroscience)

**Y21-22 Milestones**

- ☑ Began EEG-task and audiological sessions, designed machine learning classifier, and completed data pre-processing pipeline

**Y22-23 Milestones**

- ☑ Completed all audiological, cognitive, and EEG-task sessions for entire civilian cohort and 34 Veterans (Aim 1); refined classifier; recruitment begun for test-retest reliability (Aim 2); began automated test protocol for non-specialists (Aim 3)

**Y23-24 Goals**

- ☐ Complete data collection for remaining Veteran participants; test classifier; complete test-retest reliability and demonstrate approach in austere environment; establish licensing agreements; submit manuscripts for publication

Budget Expenditure to Date: \$1,154,783

9. APPENDICES:

N/A