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Auditory Considerations for Command and Control in Multinational Environments

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I have no actual or apparent conflicts to disclose

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Evaluation of Fitness for Duty

The combination of

The critical importance of hearing to military operations

and

The high levels of noise in military environments

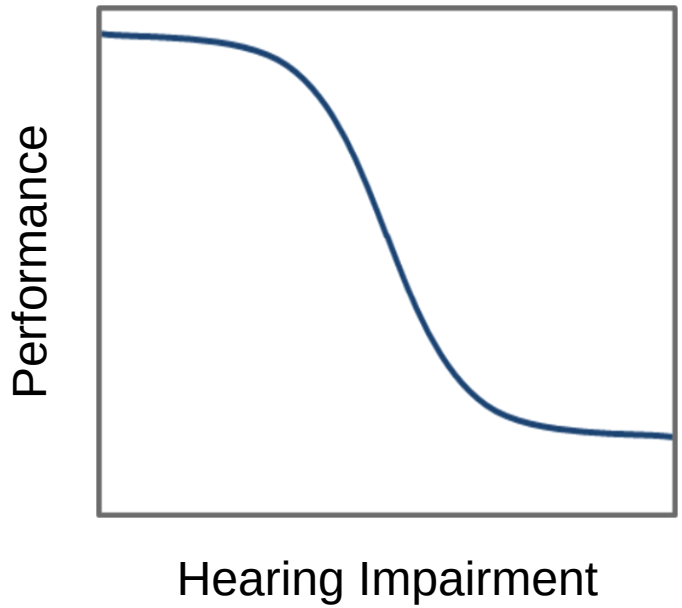
and

The prevalence of hearing loss in the military

Makes hearing one of the top readiness issues in the DoD

General Approach

The goal is to characterize the function relating ***Operational Performance*** to ***Auditory Acuity***



Needed to:

- *Establish evidence-based auditory fitness-for-duty standards*
- Provide Training on Hearing Protection Devices (HPDs)
- Develop and select new HPDs
- Justify the use of engineering noise controls

HOMESTATION INSTRUMENTATION TRAINING SYSTEM (HITS)

- **Hearing Loss Simulator**
  - Microphone on insert earphone passes through direct sound
  - Attenuation of plug + masking noise can simulate any audiogram or HPD
- **MILES Gear**
  - Vests and halos with sensors, M4 rifles equipped with a laser.
- **HITS Gear**
  - RF Transmitter allows real-time tracking of all soldier movements and engagements.

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Overview of Exercise

- **Waypoint list structured such that:**
  - **Each fire team must hit each of the other teams' starting points and an interior waypoint**
  - **Minimum distance/terrain required for each team is balanced**
  - **Some waypoints common and some unique across teams**
  - **Intermediate points can be hit in any order, so team must plan route**
  - **Team's end point in one round is their starting point for next round**
- **Four rounds in each rotation**
  - **Mean time of round ~18 minutes**
- **HL profiles switched between rounds**
- **After 4 rounds, each team had experienced each of 4 HL profiles**

Mean Composite Score vs. Hearing Condition

(Groups separated by Team Skill)

Composite Score:

+3 pts. per enemy KIA

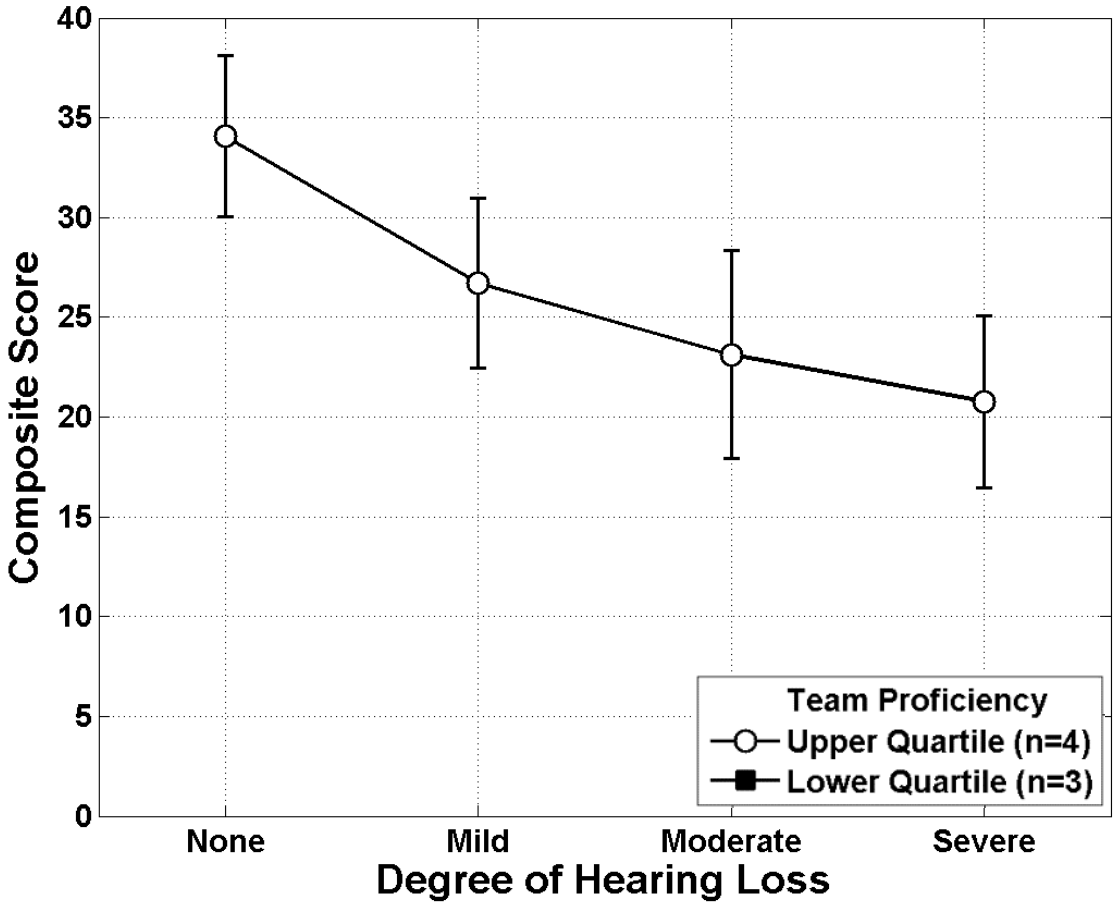
+3 pts. per surviving team member

+5 pts. per assigned waypoint

-5 pts. per unassigned waypoint

-5 pts. for hitting endpoint before hitting all intermediate waypoints

-10 pts. per fratricide (i.e., friendly fire casualty)



Error bars represent **1.515** standard errors of the mean, such that conditions with non-overlapping error bars represent statistical significance at the $p<0.05$ level on a ***one-tailed*** t-test with a Bonferroni correction for ***three*** comparisons

Performance in Noise: The Impact of Reduced Speech Intelligibility on Reaction Time in a Naval Combat Environment

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[2]Walter Reed National Military Medical Center, Bethesda, MD;
[3]Naval Surface Warfare Center, Dahlgren, VA;
[4]Sonalysts, Inc., Virginia Beach, VA

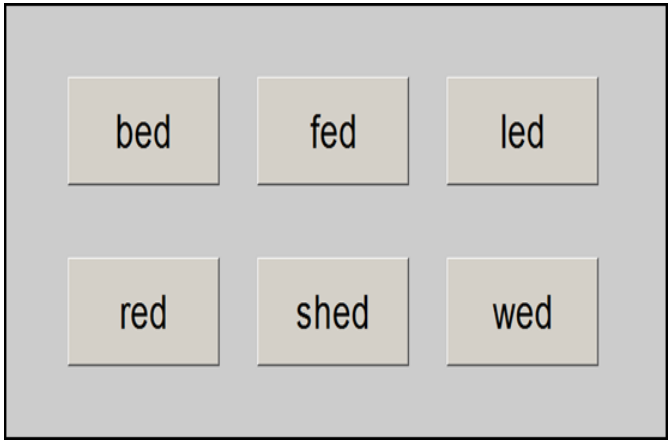
Oct 10, 2017

Combat Scenario

- CIC Environment - SME developed scenario incorporates elements and action items a watchstander might encounter in a CIC deployment on an Aegis destroyer.
- Events were scripted but participant/confederate were allowed natural interactions.
- One overall scenario split into segments each with different hearing/noise condition.
- Participants gathered information from TACSIT, CHAT, and Electro Optics display well as from audio communications with participants or confederates.
- Operational Effectiveness – Performance was scored based on ratings from confederates, self ratings, response accuracy, and situational awareness measures
- Other behavioral measures included: An eye tracker, recorded voices analysis.

Modified Rhyme Test

- **Modified Rhyme Test –** A speech intelligibility test which asks listeners to pick the spoken word from a six-word list of rhyming or similar-sounding monosyllabic English words.
  - Assesses the impact of experimental hearing manipulations independent of scenario environment (e.g., external cues such as visual information, training, and experience). Also used for validation.
  - Adaptive MRT – Used MRT based performance to determine Signal to Noise Ratio unique to each participant that matched specific Speech Intelligibility levels across all participant (50%,65%,80% and 100%).
  - Normal MRT was given throughout to again validate experimental conditions.

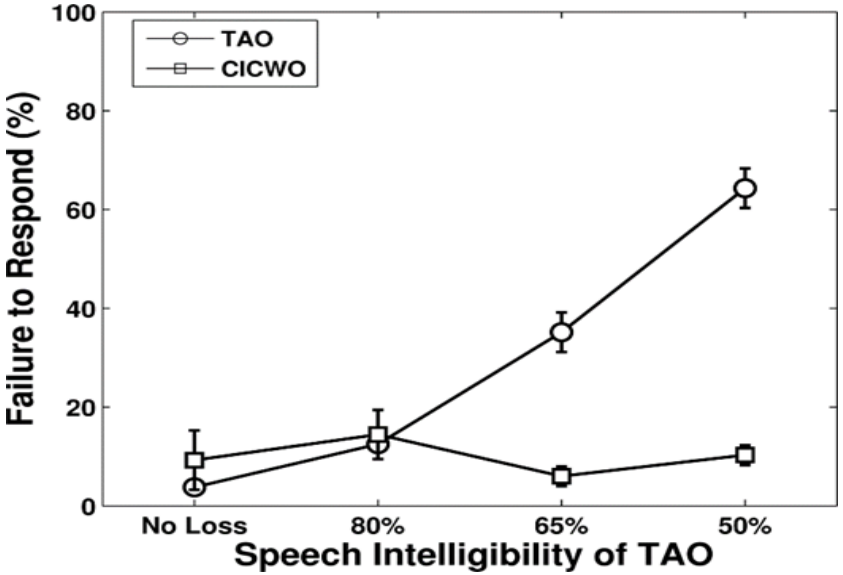


"You will mark SHED please"

Methods Overview

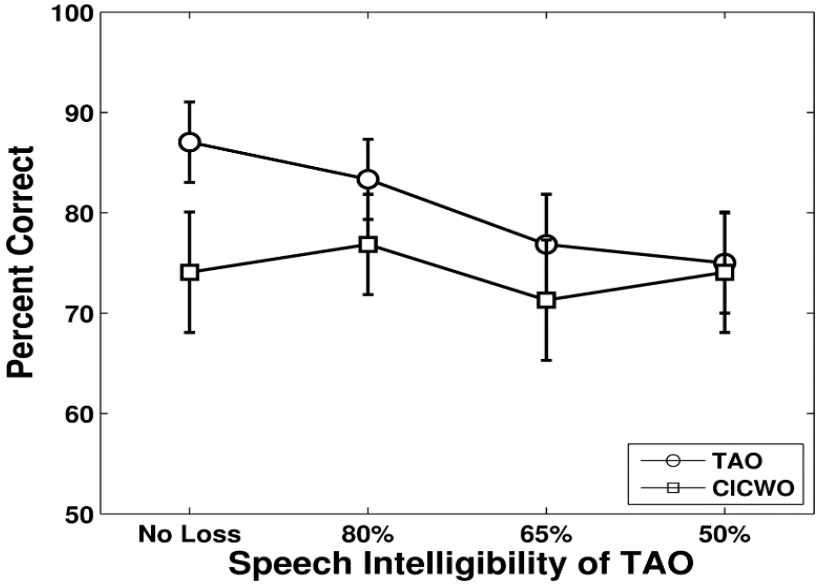
- Participants – 36 participants with Combat Information Center (CIC) experience from the Center for Surface Combat Systems Unit Dam.
- Two participants served concurrently as either Tactical Action Officer (TAO) or CIC Watch Officer (CICWO).
- Two Navy Command SME Confederates played roles of all other watch standers as needed by the participants.
- Every participant completed 8 scenario segments, which repeated each of 4 speech intelligibility conditions twice.
- TAO experienced the 4 levels of Speech Intelligibility conditions.
- CICWO had clean comms throughout.

Performance – Information



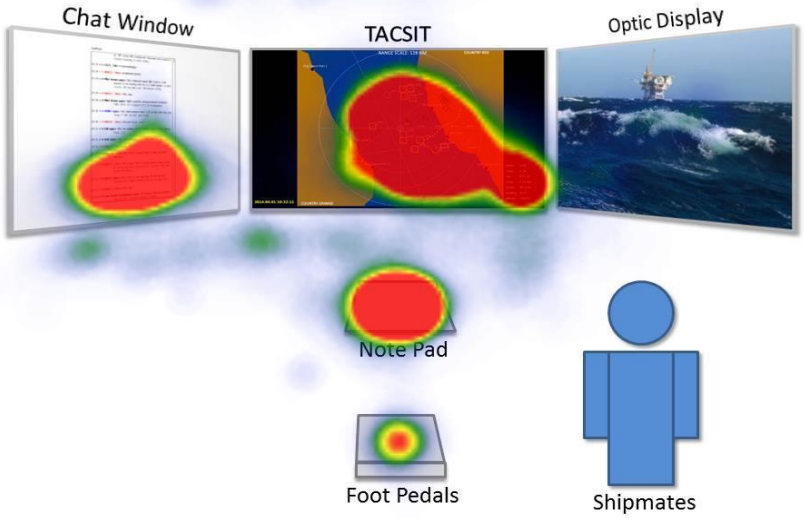
Participants acknowledgment rate suffered as noise levels increased. Graph shows the percentage of communications participants failed to respond to when direct at them. Failed responses results in missed information or requires others to pick up the slack.

Participants showed that their situation awareness was affected by the different noise conditions. Situation awareness (SA) was measured using a multiple choice questionnaire for participants to answer after each segment.

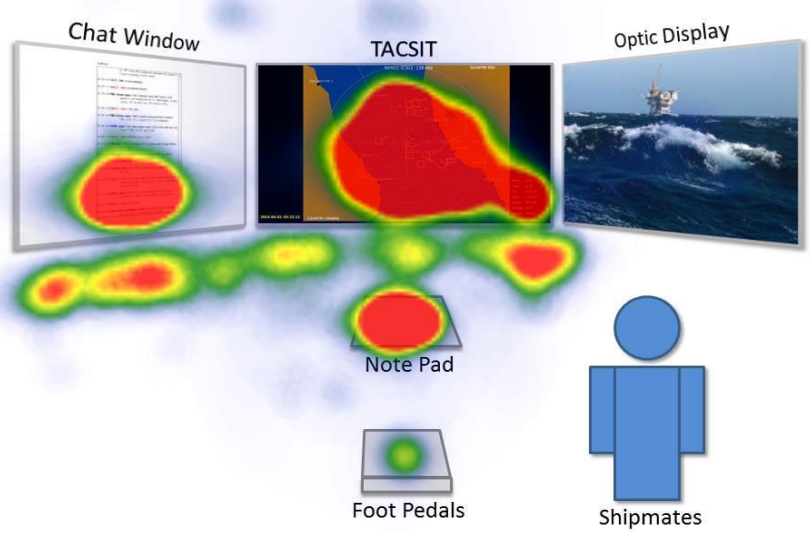


Compensation - Attention Shift

Sailors shifted focus of attention away from visual information to focus on their hearing during hard to hear conditions.



No Noise Condition



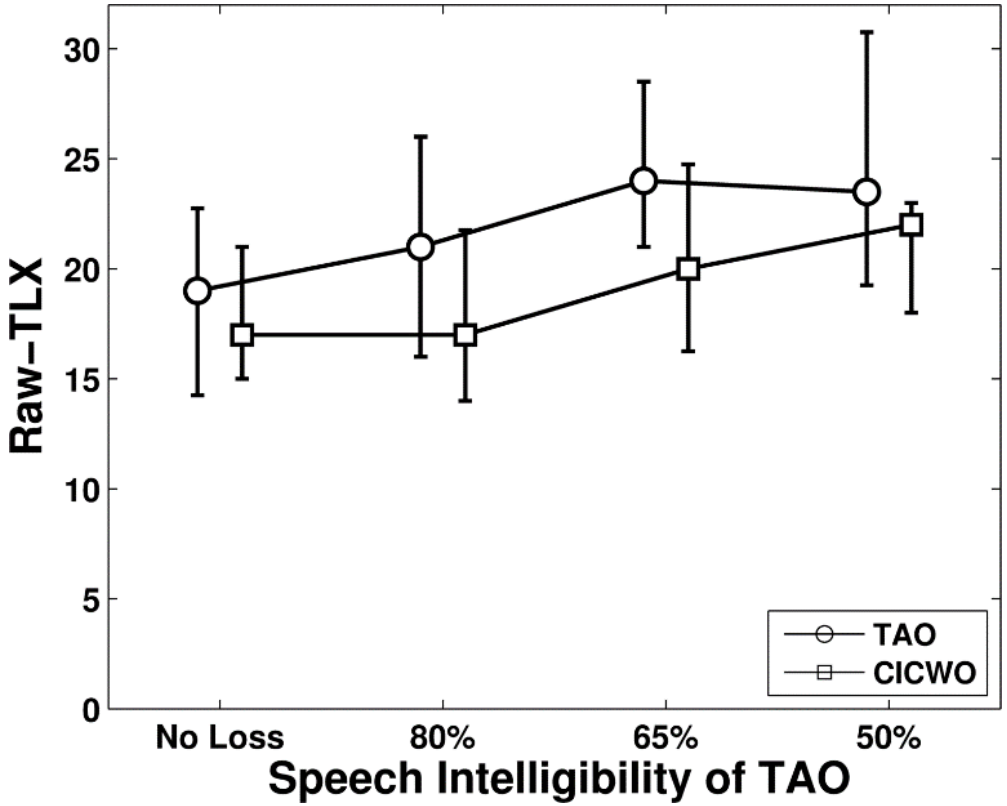
Severe Noise Condition

Consolidated Visual focus pattern of all Sailor under different Noise conditions. Red indicates increased fixation time in those areas.

Shift of attention away from critical visual information may result in loss of situational awareness and missed information especially when operation tempo is increased.

Performance - Workload

Both participants rated significantly higher workload as noise conditions increased. This includes the CICWO who experienced no noise in comms.

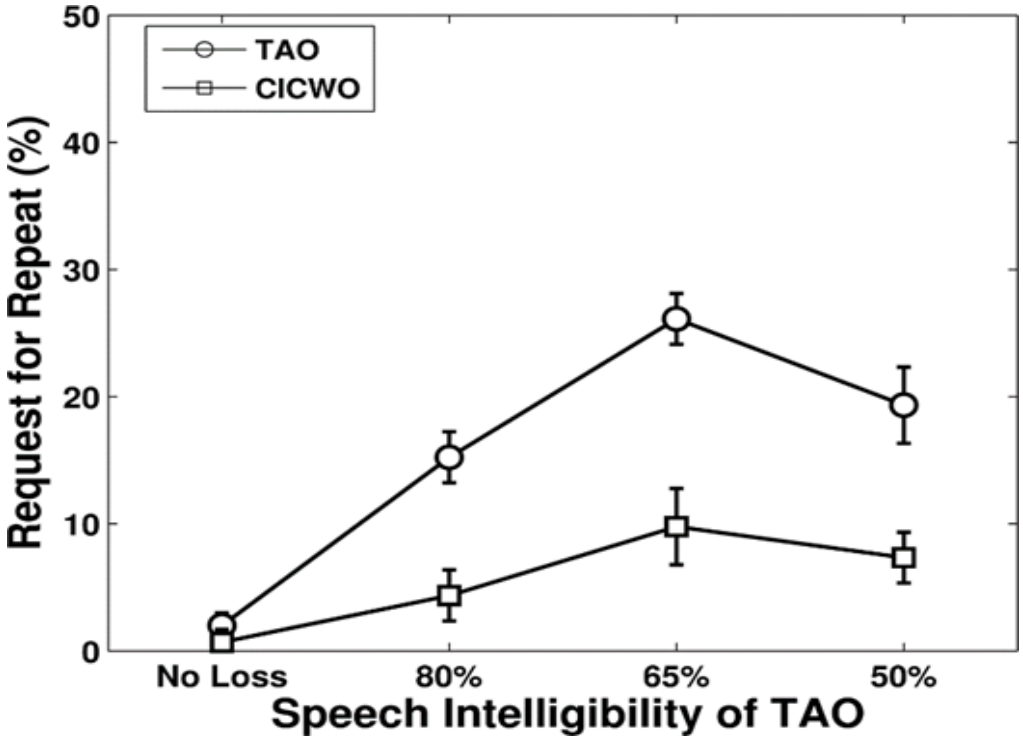


Results not only indicative of the challenge of communicating in noise, but also the shift of workload to others when team members are challenged.

Compensation - Communications

Because of hearing challenges participants altered behavior in order to compensate

Participants number of requests for repeat backs increased up to the 65% Speech Intelligibility level then drops for the worst speech intelligibility level probably due to participants not hearing the communication in the first place.



Repeat backs may delay other's ability to communicate because communication channels are shared among many across and between ships and services.

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What About Coalition Warfare?

Military environments often combine **noise** and **hearing loss**

This is a hazard even for **Native English Speakers**

What happens when talker, listener, or both are **non-native?**

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Battle of Britain Bunker Uxbridge, England

"The girls had to speak perfect English…
what if you had one Scottish and one Welsh, trying to talk to one another"

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NATO HFM-285

NATO Panel chartered to look at influence that Native and Non-Native English Speech might have on military operations…..

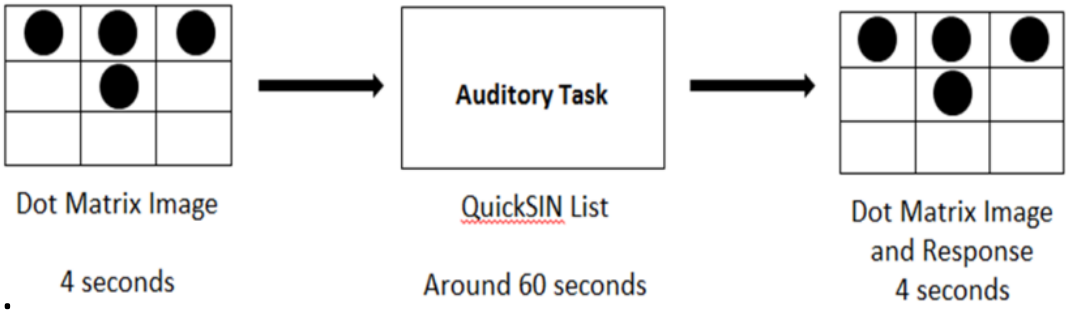
“Speech Understanding of English language in Native and non-Native speakers/listeners in NATO with and without Hearing Deficits”

Investigation of Effortful Listening

(Nakashima, Cai and Vartanian, DRDC, in preparation)

- **Question: Do non-native speakers have more difficulty understanding speech in noise when a secondary task is added?**

- Used QuickSIN (primary) and a Dot Matrix task (secondary)



- Baseline tasks:
  - Hearing screening
  - Language experience and proficiency questionnaire (LEAP-Q)
  - Speech, Spatial and Qualities of Hearing scale (SSQ12)
  - Working Memory (WM) tasks: word span, matrix span, operation span

Results: Baseline Working Memory

Working Memory Scores

	Native (n = 12)	Non-native (n = 12)
Word span score	6.0 ± 0.8	5.3 ± 1.5
Matrix span score	4.1 ± 0.6	3.9 ± 0.8
Complex span, partial score	18.1 ± 6.3	17.2 ± 5.1

Correlations

	Matrix span score	QuickSIN without load	QuickSIN with load
Word span score	r = 0.693 p < 0.001	r = -0.609 p = 0.002	r = -0.592 p = 0.002

- No significant differences between native and non-native group
- No correlation between simple span and complex span scores
- Significant correlation between 1) word span and matrix span and 2) word span and QuickSIN

Results: QuickSIN With and Without Load

	Native (n = 12)	Non-native (n = 12)
*SNR50 Without load	-0.19 ± 1.2	4.5 ± 3.3
**SNR50 With load	-0.19 ± 1.3	4.3 ± 3.6

*t(11) = -4.7, p < 0.001
**t(11) = -4.1, P = 0.001

- Average SRT from "randomized" lists 1-12 (6 for each load condition)
- Differences between native and non-native groups likely due to language experience (no difference in WM scores)

	Early learners (n = 6)	Late learners (n = 6)
SNR50 Without load	3.1 ± 3.4	5.9 ± 2.8
*SNR50 With load	2.0 ± 2.6	6.6 ± 3.0

*Mann-Whitney U = 5, p = 0.04

- Late learners (> 7 years old) may have more difficulty in load condition.

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Opportunity: Trident Juncture

- **When**: from 25 October to 7 November 2018.
- **Who**: Around 50,000 participants from 31 NATO and partner countries.
- **Components**: Around 250 aircraft, 65 vessels and up to 10,000 vehicles.
- **Location**: Central and eastern Norway;

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Opportunity: Trident Juncture

Invited to participate as part of the

Allied Command Transformation Emerging Medical Capability Projects

Transformational Activity examining the Modular Approach to Medical Support

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Study Description

Study consisted of a survey given to participants during their break times (typically in Canteen) at three sites

- **JWC Stavanger**
- **Directorate of Health Oslo**
- **JFCNP Naples**

Different versions were given for
- Native Speakers of English
- Non-Native Speakers of English

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Study Description

Data Collection Summary:

	JWC (LIVEX)	JWC (CPX)	JFCNP (CPX)	Oslo (CPX)
Native	6	43	14	1
Non-Native	19	79	13	9
Totals	**25**	**122**	**27**	**10**

At JWC Stavanger, data was collected primarily in the canteen while EXCON participants were on a coffee break or eating lunch. However, about a third of the data was collected by going to the various work areas of the EXCON participants and recruiting participants during low tempo segments of the exercise.

Total: 63 Native; 120 Non-Native

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Survey Components: Demographics

What is your Native Language?
What is your English "STANAG" language level? (Circle) 0 (no proficiency) 1 (survival) 2 (functional) 3 (professional) 4 (expert) 5 (highly-articulate native)
At what age did you start learning English?
How many years have you spent working or studying in an English environment?

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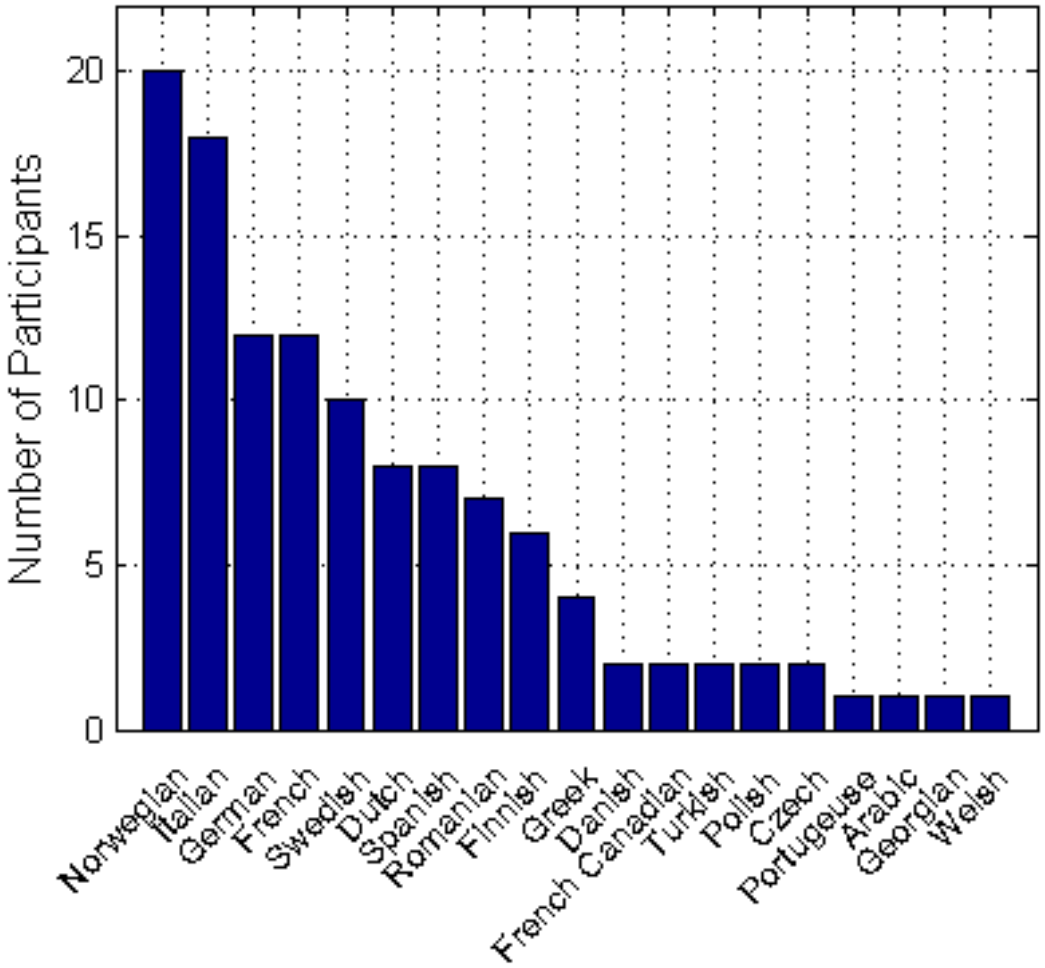
Survey Components: Demographics



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Survey Components: Evaluation of Difficulty

1. In a quiet room, how much difficulty do you have understanding…
2. In a noisy room, how much difficulty do you have understanding…
3. When talking to one person on the phone or on radio, how much difficulty do you have understanding…
4. When monitoring multiple talkers on a radio net, how much difficulty do you have understanding…

A Native English talker speaking English: (Easy) 0 – 1 – 2 – 3 – 4 – 5 – 6 – 7 – 8 – 9 (Hard)

A Non-Native English talker from another NATO nation speaking English: (Easy) 0 – 1 – 2 – 3 – 4 – 5 – 6 – 7 – 8 – 9 (Hard)

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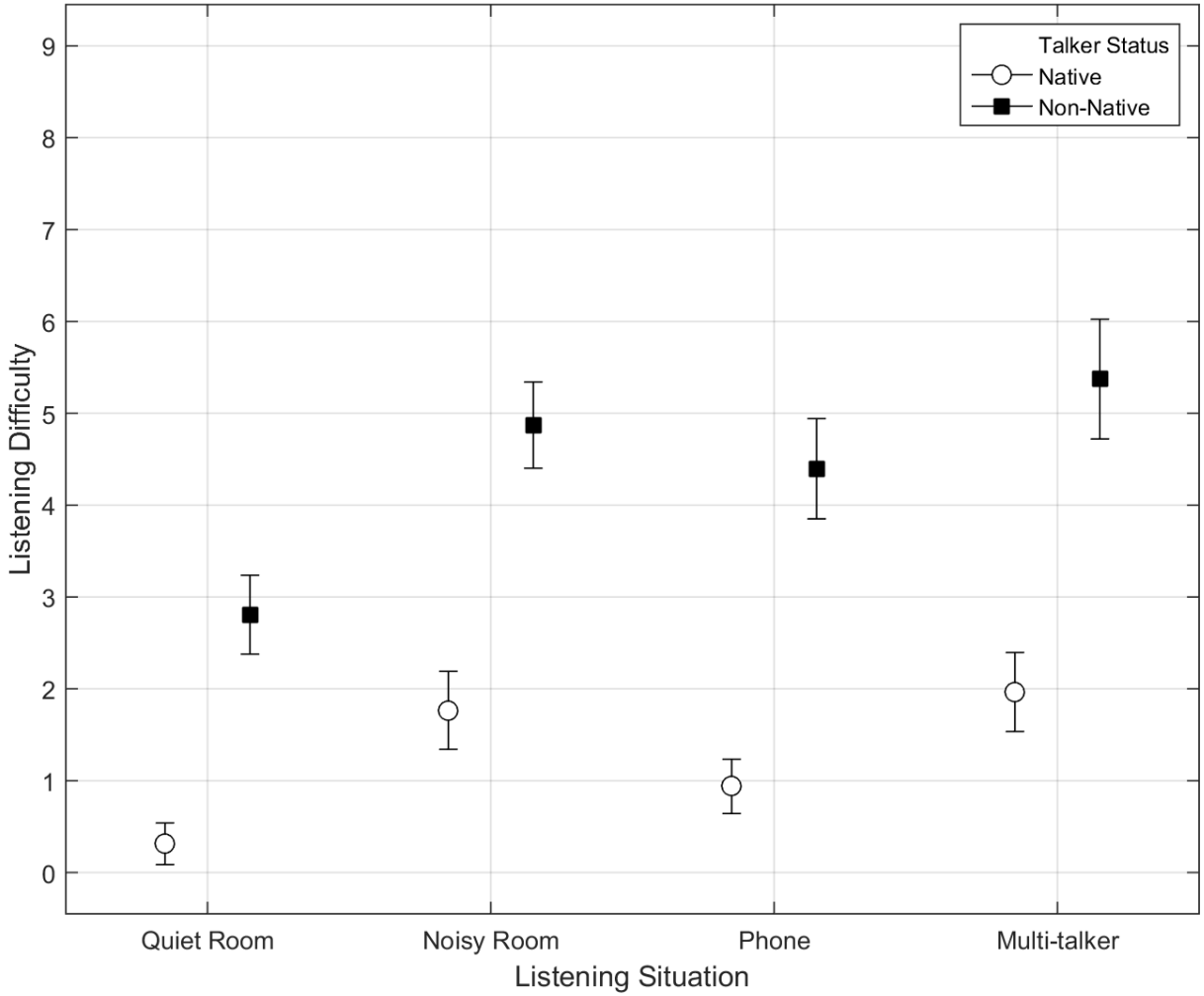
Survey Components: Evaluation of Difficulty



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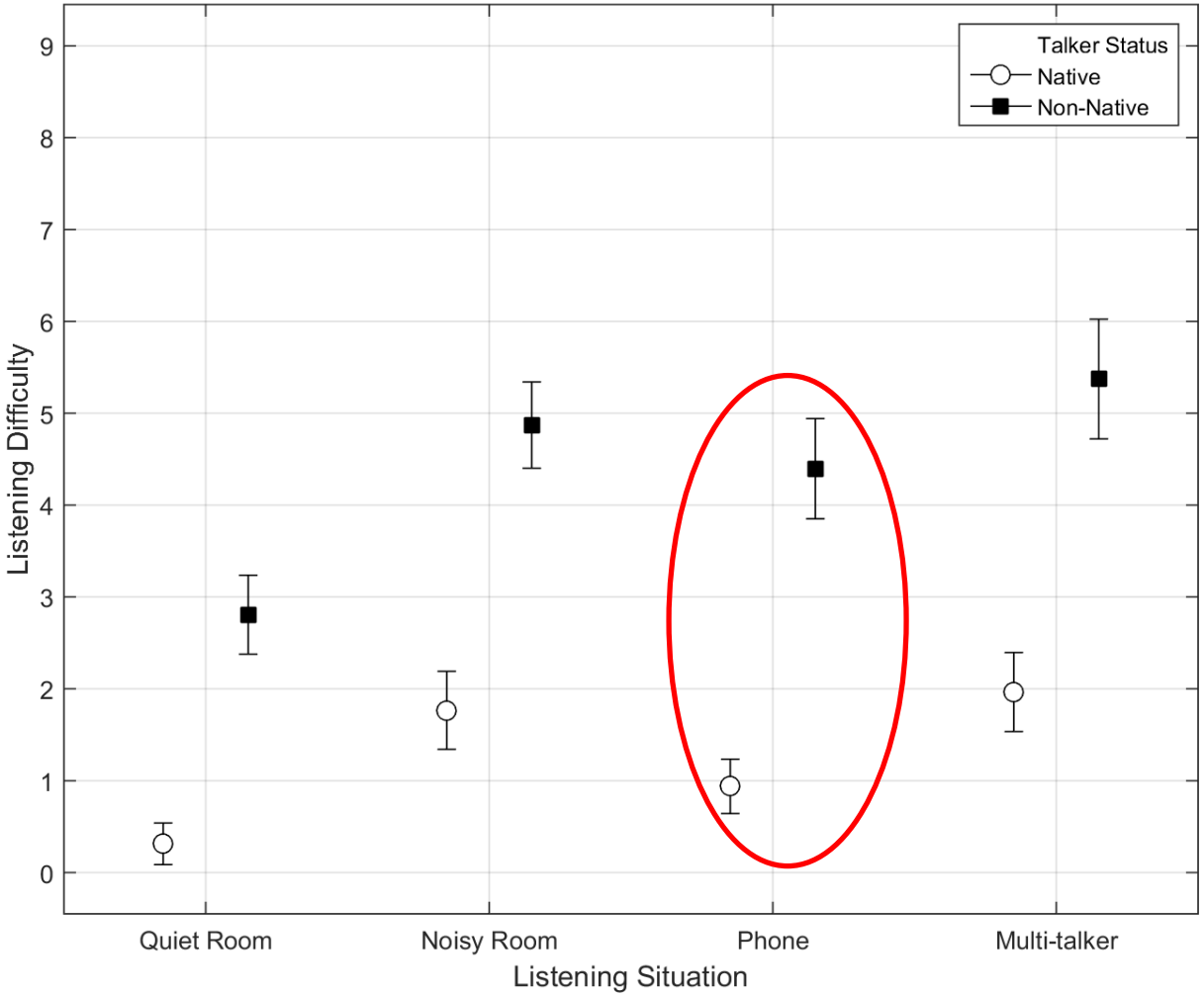
Survey Components: Evaluation of Difficulty

Phone less difficult than Noisy Room or Multitalker Radio



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A Native English talker speaking English:	(Easy) 0 – 1 – 2 – 3 – 4 – 5 – 6 – 7 – 8 – 9 (Hard)
A Native Talker of your own language speaking English:	(Easy) 0 – 1 – 2 – 3 – 4 – 5 – 6 – 7 – 8 – 9 (Hard)
A Non-Native English talker from another NATO nation speaking English:	(Easy) 0 – 1 – 2 – 3 – 4 – 5 – 6 – 7 – 8 – 9 (Hard)
A Native Talker of your own language, speaking your language:	(Easy) 0 – 1 – 2 – 3 – 4 – 5 – 6 – 7 – 8 – 9 (Hard)

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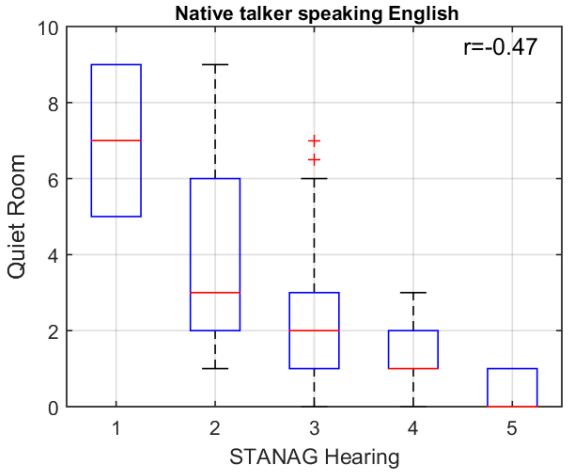
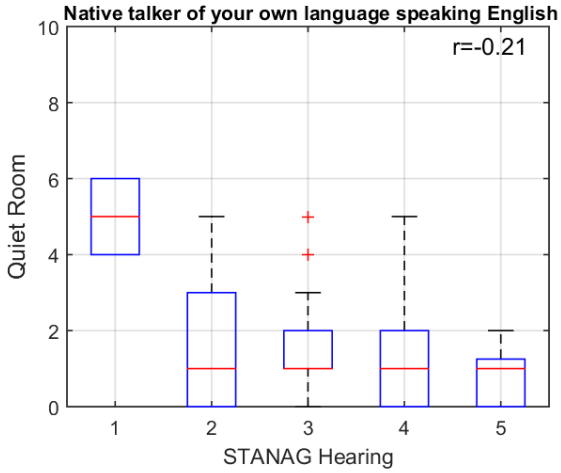
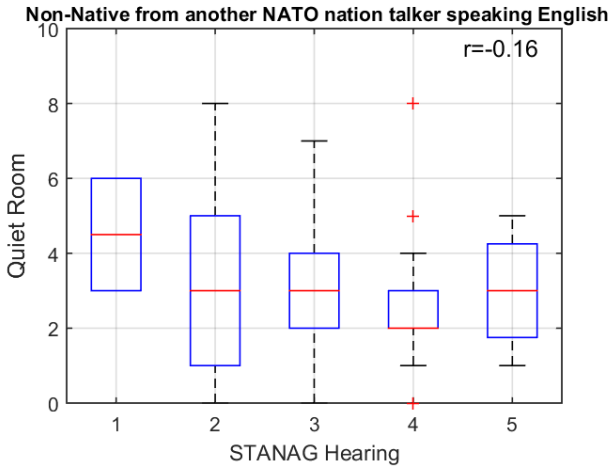
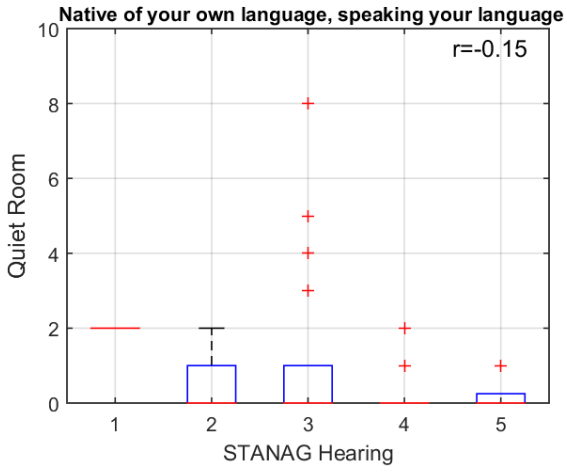
Survey Components: Quiet Room









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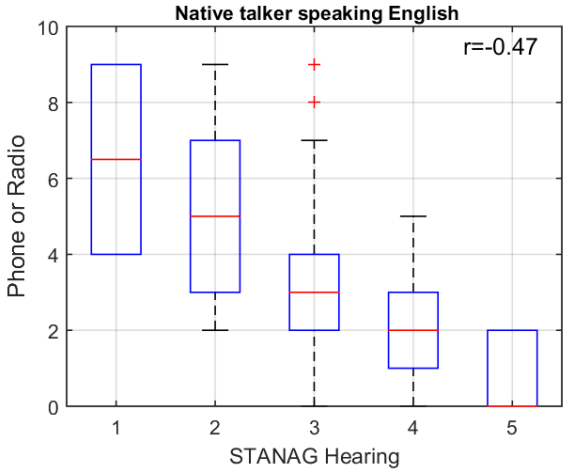
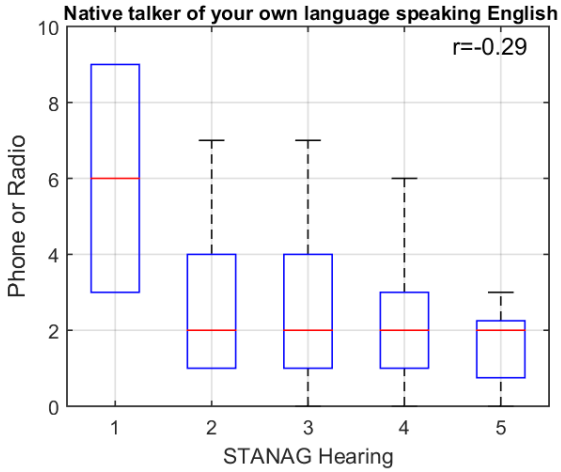
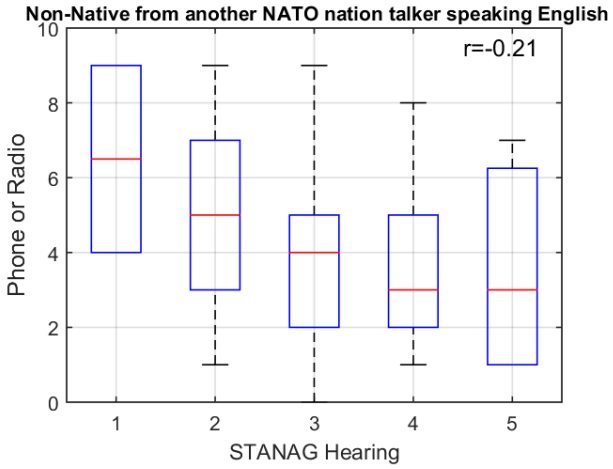
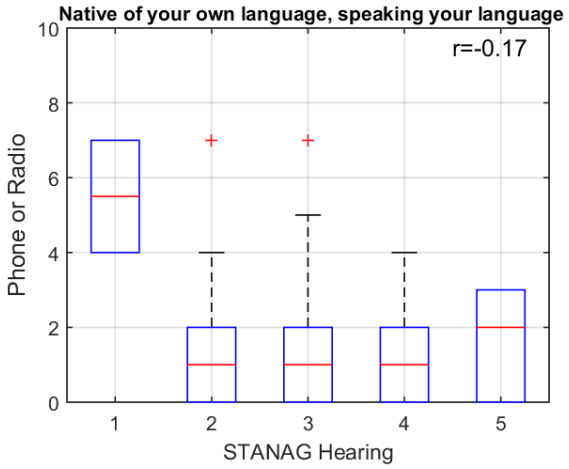
Survey Components: Phone or Radio









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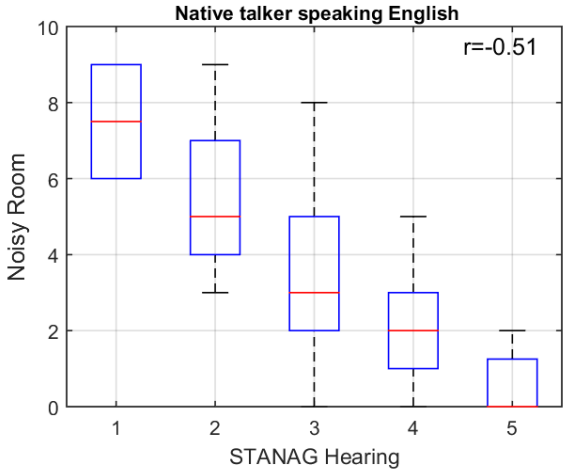
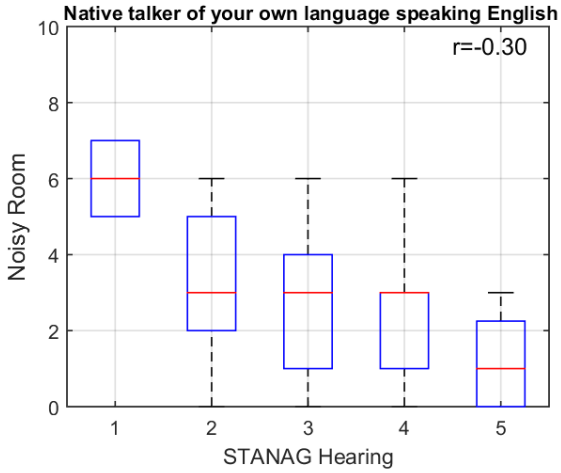
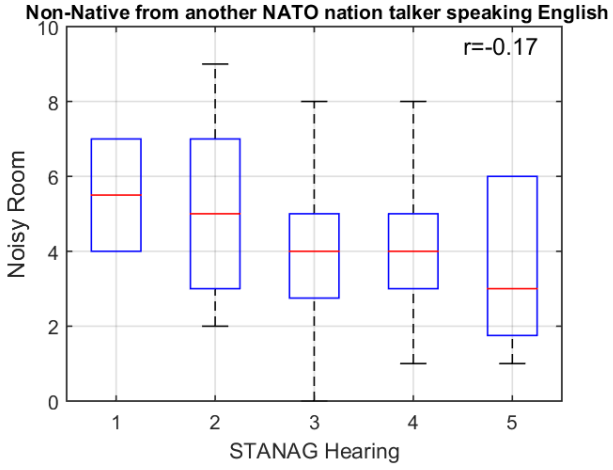
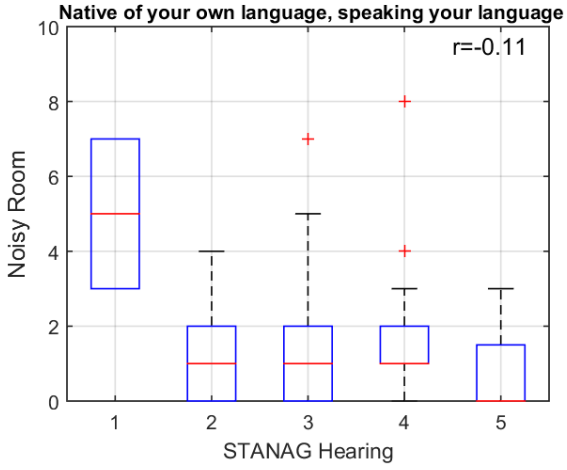
Survey Components: Noisy Room









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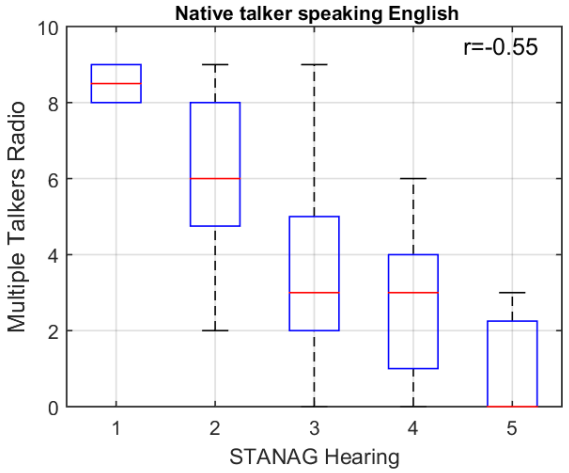
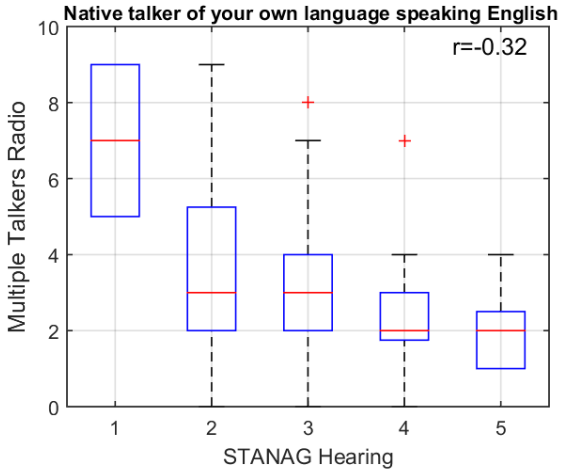
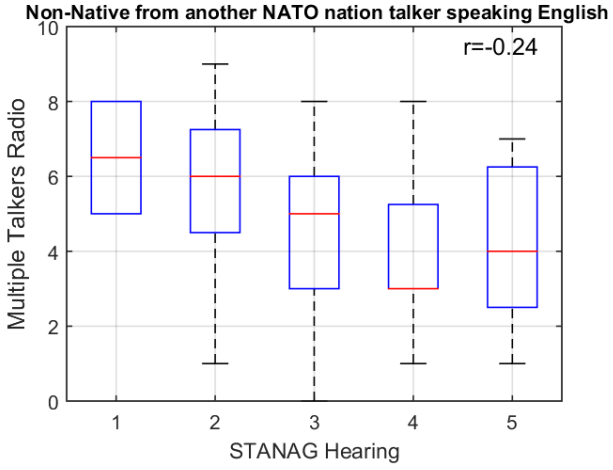
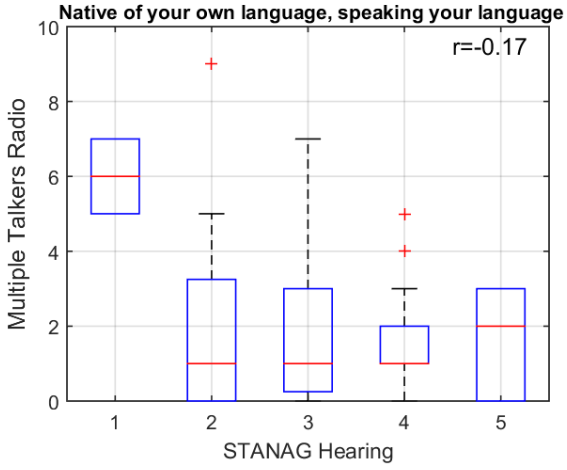
Survey Components: Multiple Talkers









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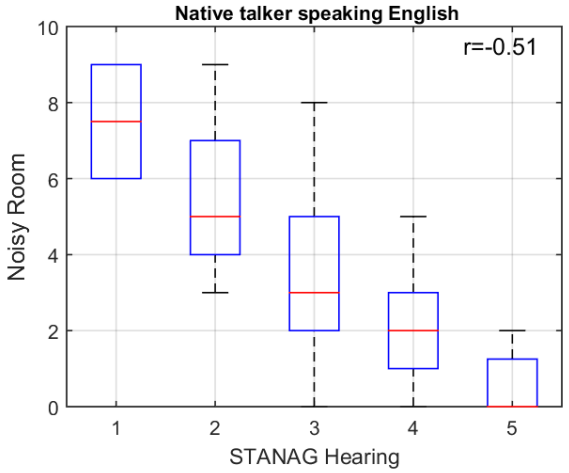
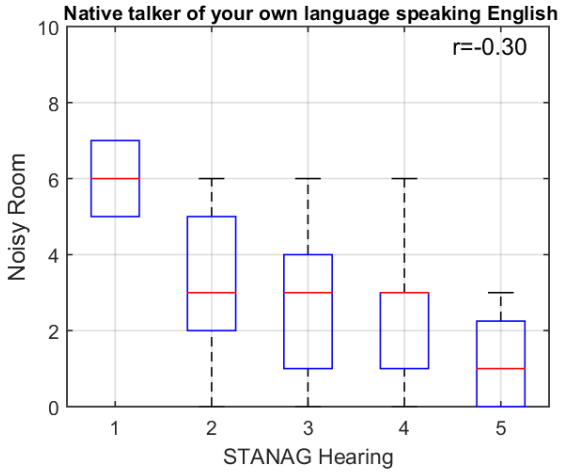
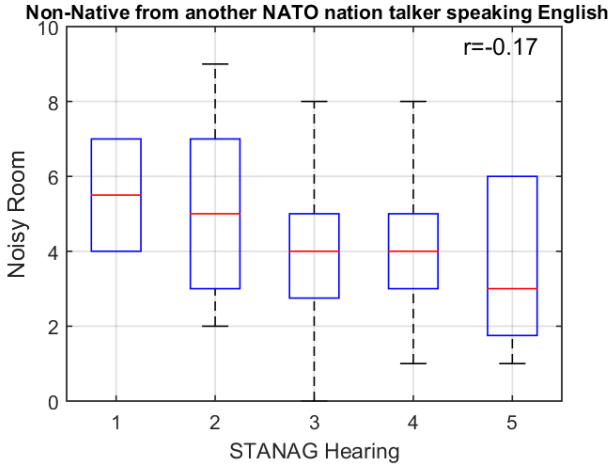
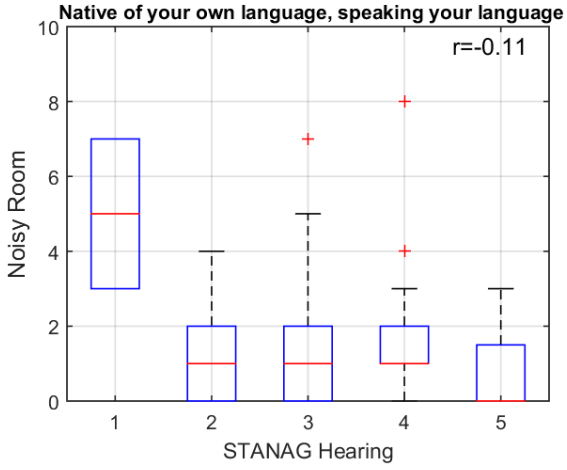
Survey Components: STANAG Hearing









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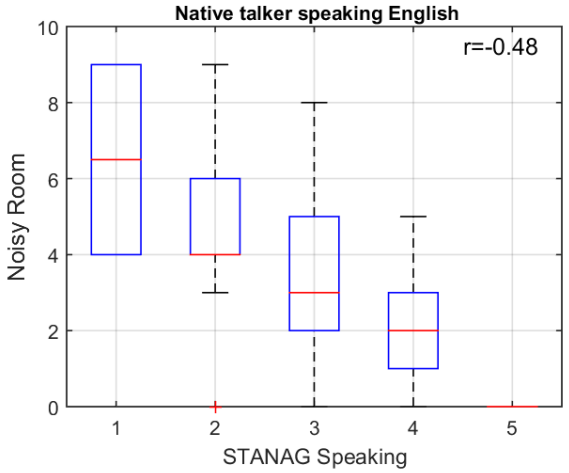
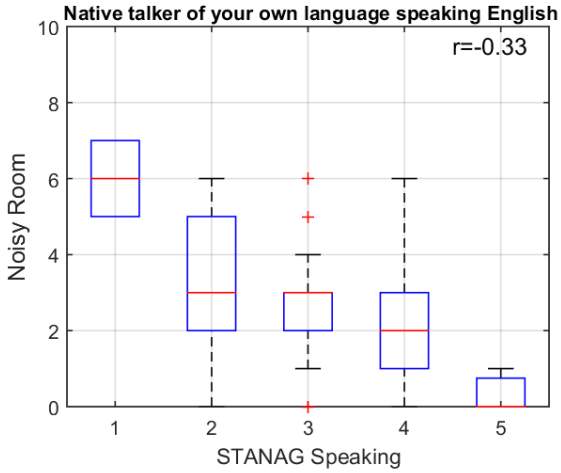
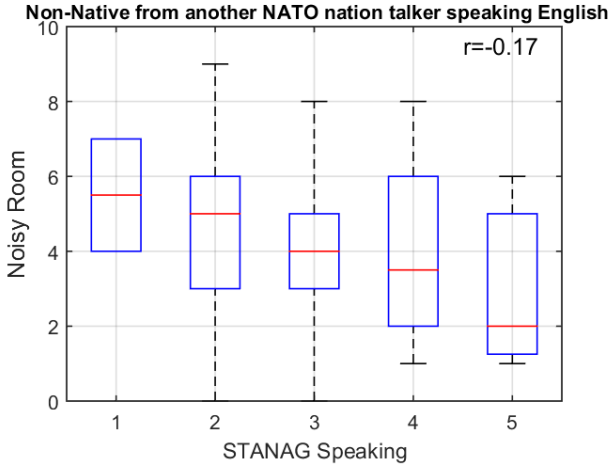
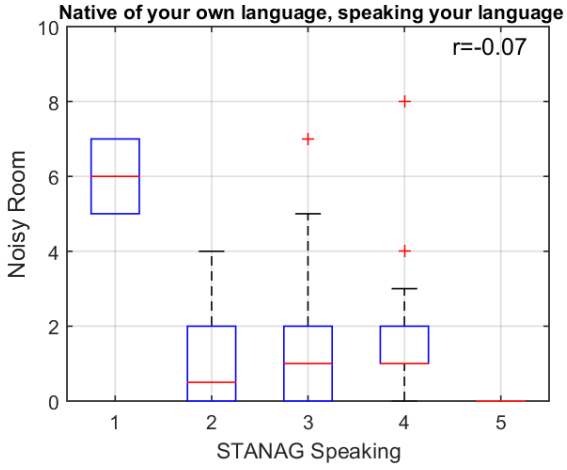
Survey Components: STANAG Speaking









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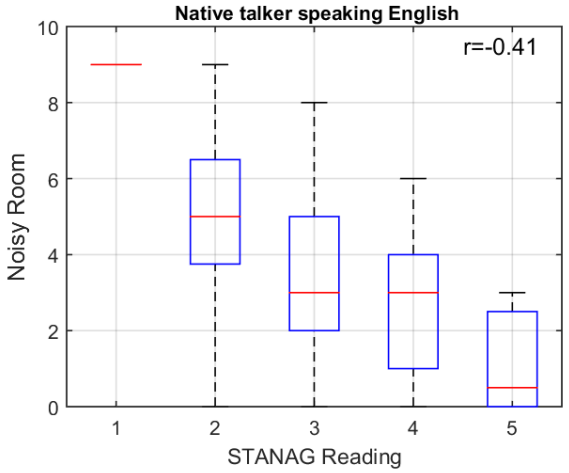
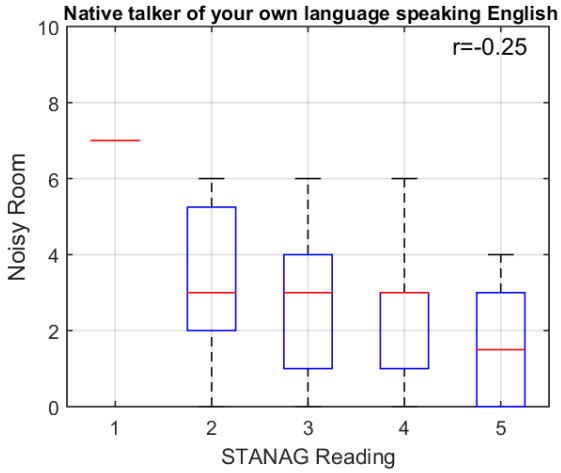
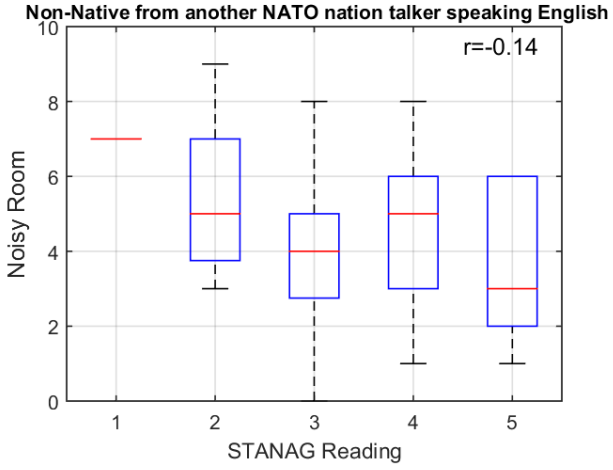
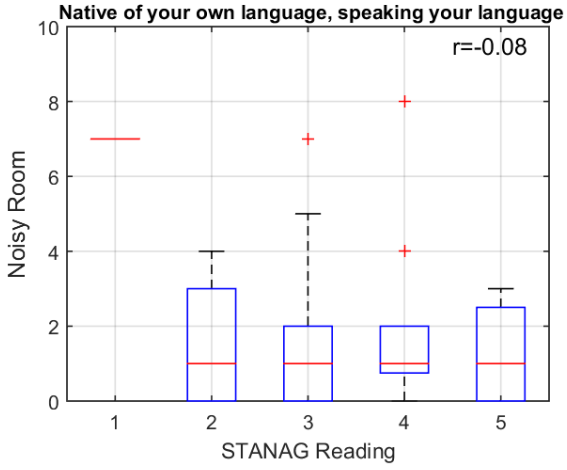
Survey Components: STANAG Reading









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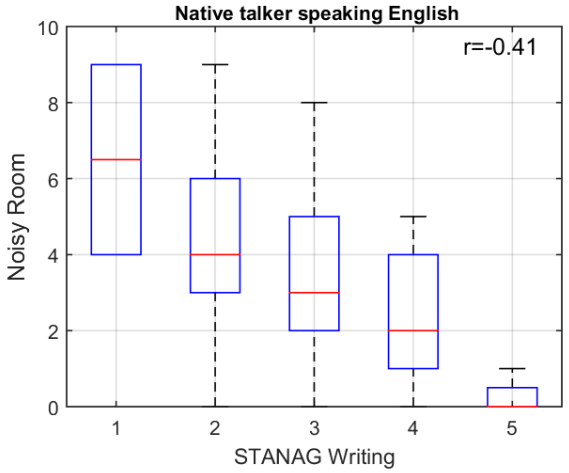
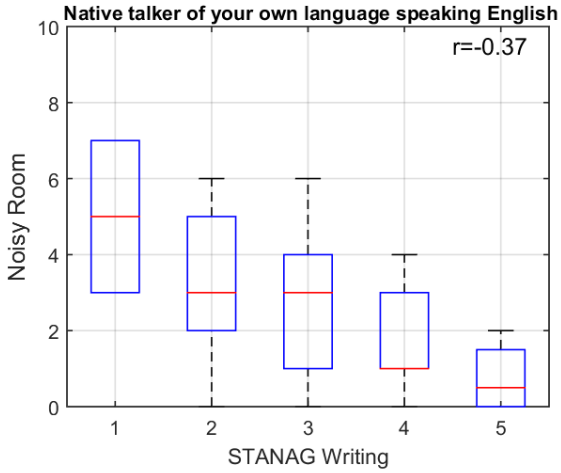
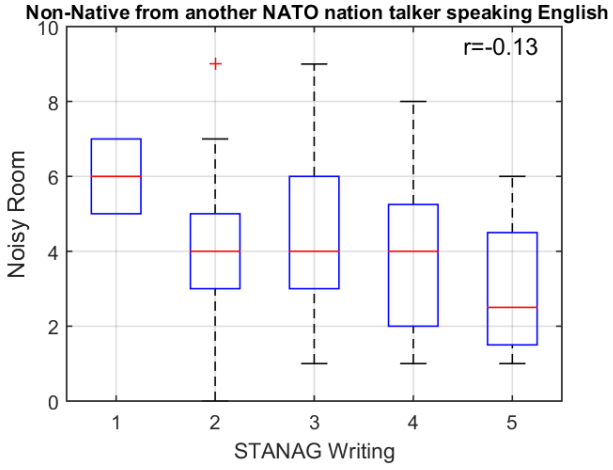
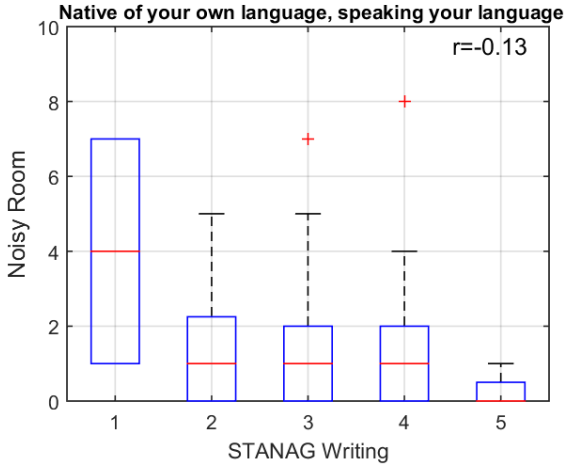
Survey Components: STANAG Writing









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Survey Components: Evaluation of Hearing Loss

Do you have any known hearing loss? (please circle one)

Don't know None Mild Moderate

STOP - THE SECTION BELOW IS COMPLETED BY THE TEST ADMINISTRATOR

Field Hearing Test- Find the quietest environment possible for this test

For this part of the test, show the participant how to rub their fingers together as strongly as possible without making a "snap" noise. Then ask them to extend their arm completely away from their ear (roughly 70 cm from the ear) and ask them if they can hear the rubbing noise. If they cannot, then have them bend their arm halfway (roughly 35 cm) and see if they can hear it. If not, have them hold the fingers right outside the ear (roughly 2 cm) and see if they can hear it. Repeat with the other ear and other arm.

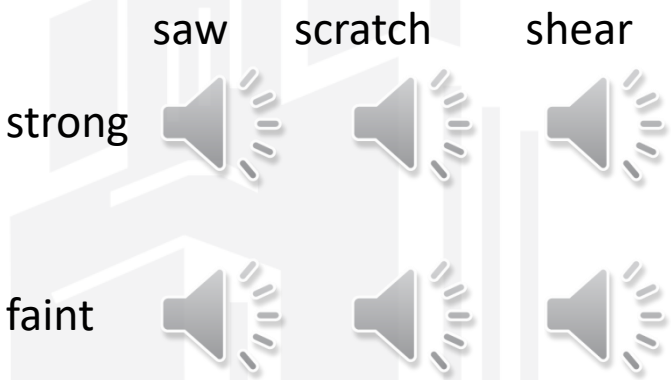
Check the box for the closest point where they could hear the sound

Right side: Arm's Length (70 cm) _____ Half-way (35 cm) _____ Close (2 cm) ____

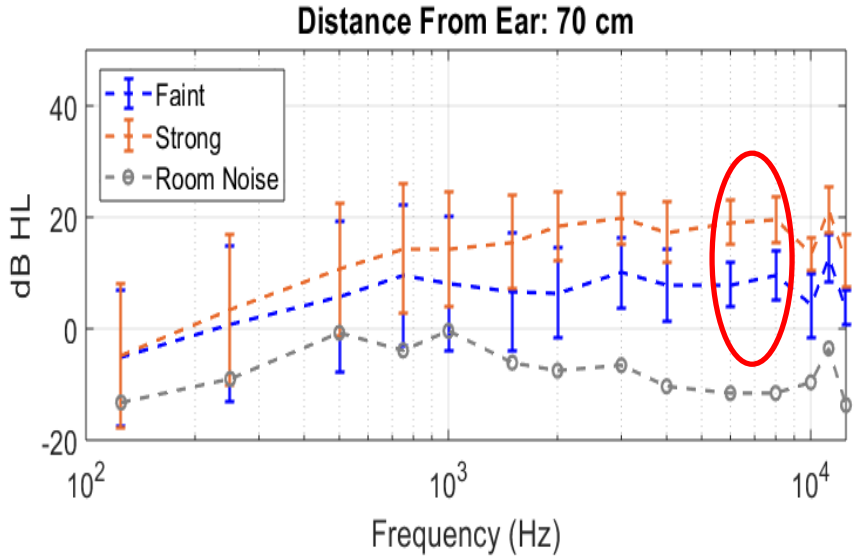
Left Side: Arm's Length (70 cm) _____ Half-way (35 cm) _____ Close (2 cm) ____

CALFRAST Results

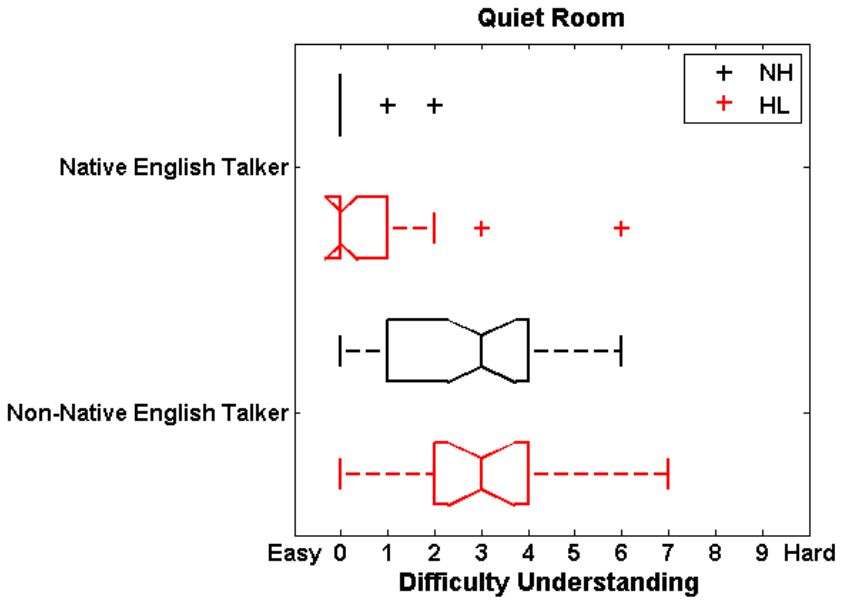
- Continual noise, not continuous
- Finger rubbing style
  - 5 2-fingered; 1 1-fingered
  - 3 “sawing” (one-direction rub)
  - 2 “scratching” (two-directions)
  - 1 “shearing” (near snapping?)
- Scratchers had more rate variability
  - 1 fast, 1 slow-to-fast
- Rest seemed to have moderate speed

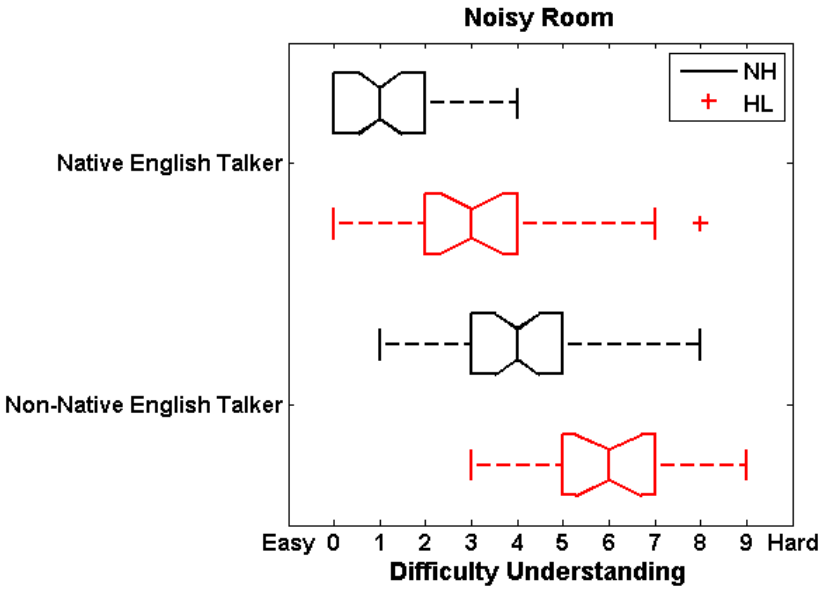


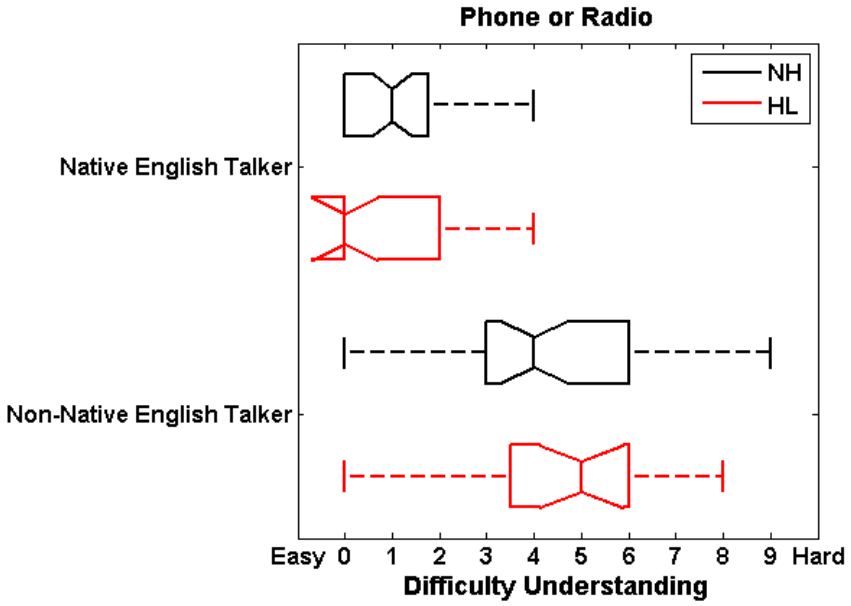
- Examined peak frequencies for audibility
  - Binned recordings by ERB
  - Got max dB values for each frequency
- *M* and *SD* spectra of 6 staff

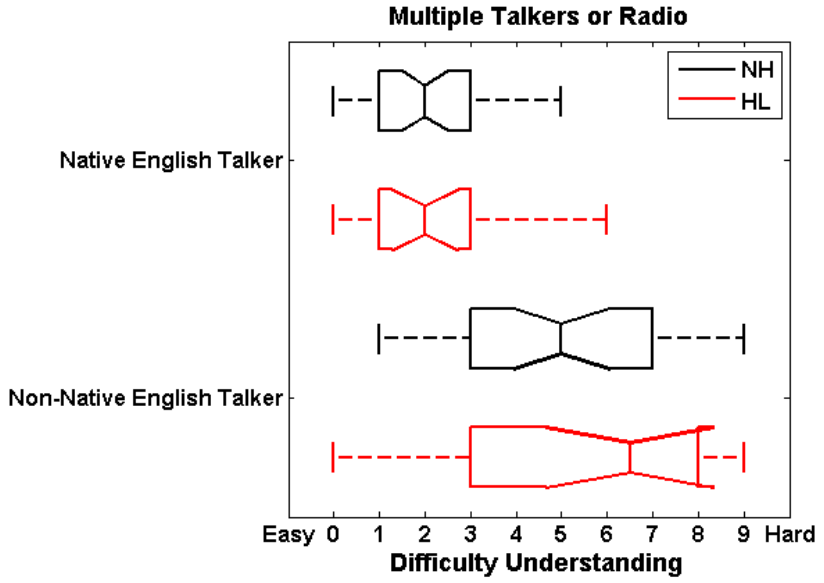


Native English Subjects – NH vs HL Comparison

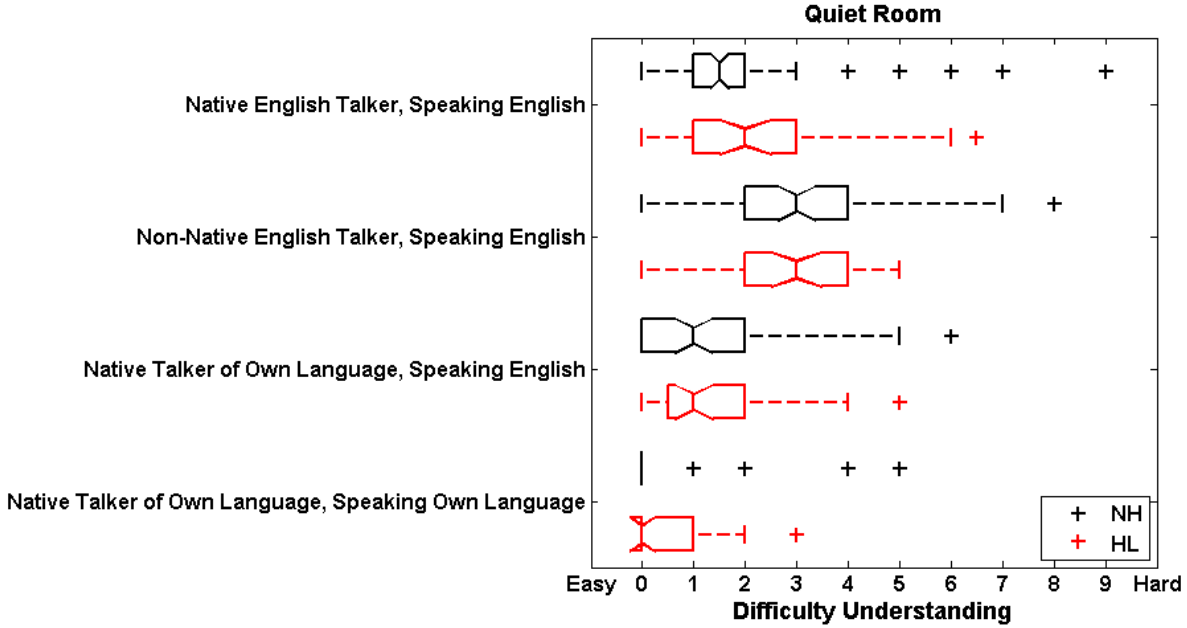


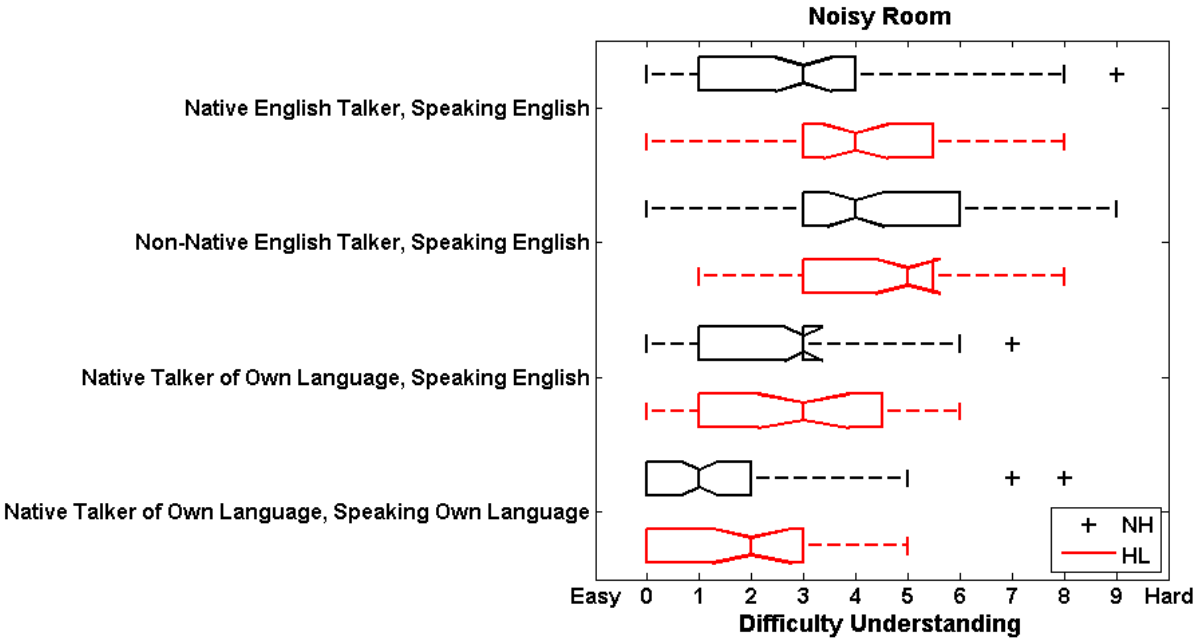




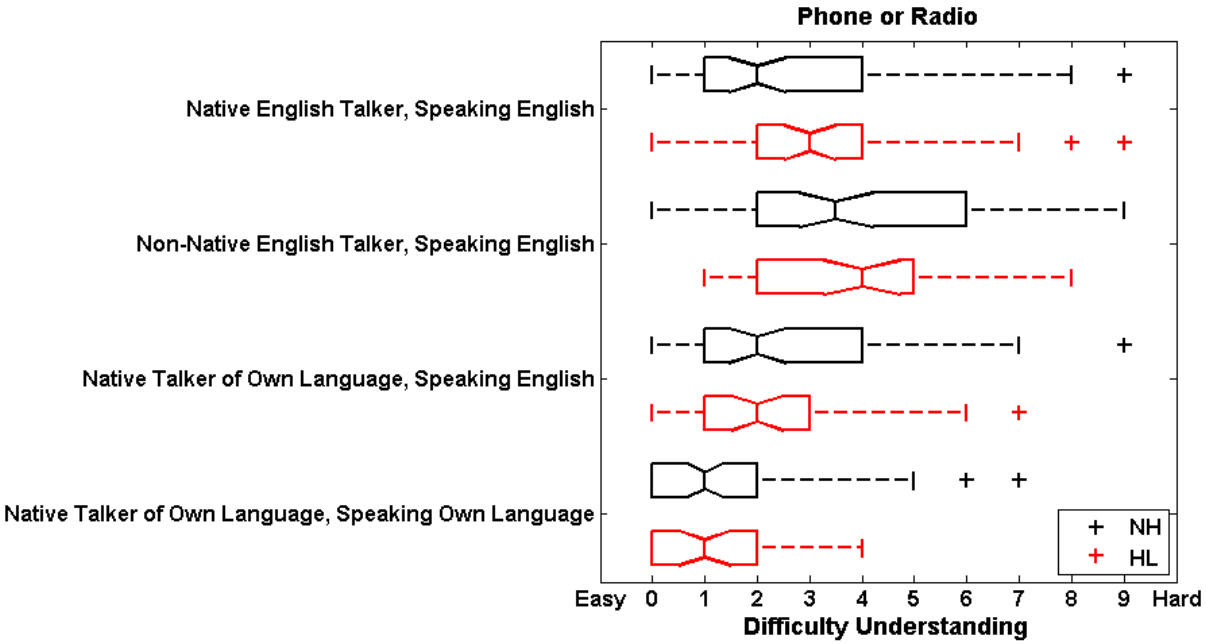


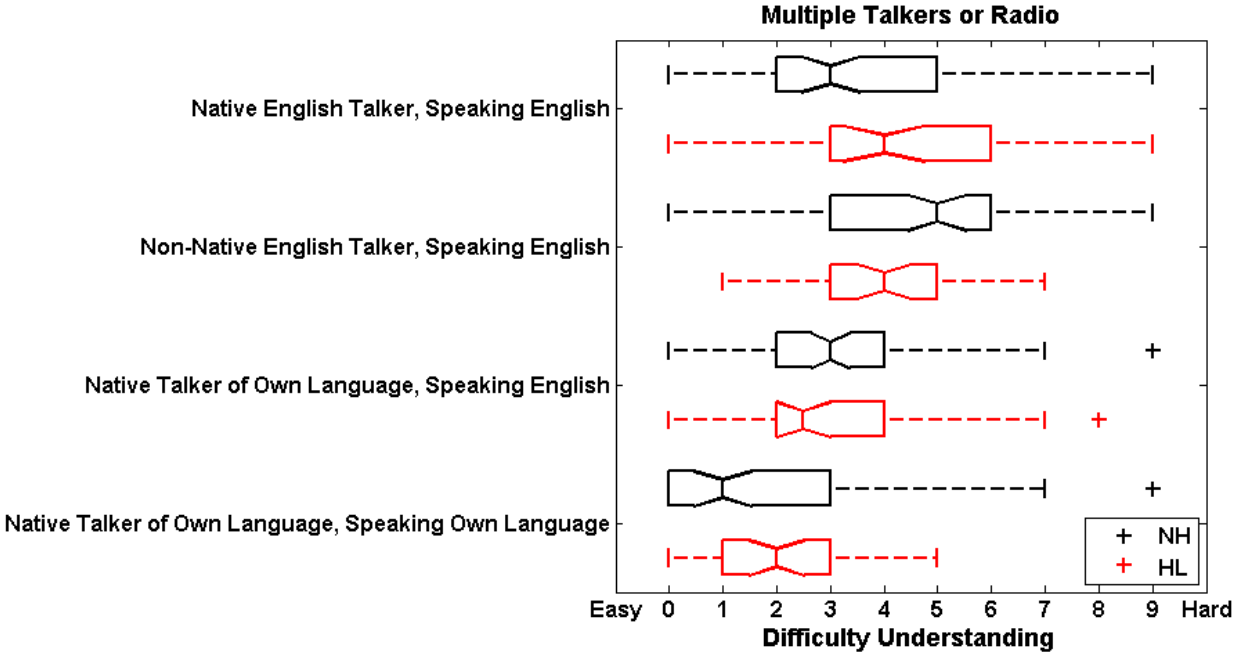
Non-Native English Subjects – NH vs HL Comparison





Non-Native English Subjects – NH vs HL Comparison





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Survey Components: Evaluation of Hearing Loss

How frequently has your mission performance been impaired by:

1. Your own difficulty in understanding spoken English?

A delay in communication or request for repetition (Never) 0 – 1 – 2 – 3 – 4 (Often)

A misunderstanding leading to an operational error (Never) 0 – 1 – 2 – 3 – 4 (Often)

Worst error: _____

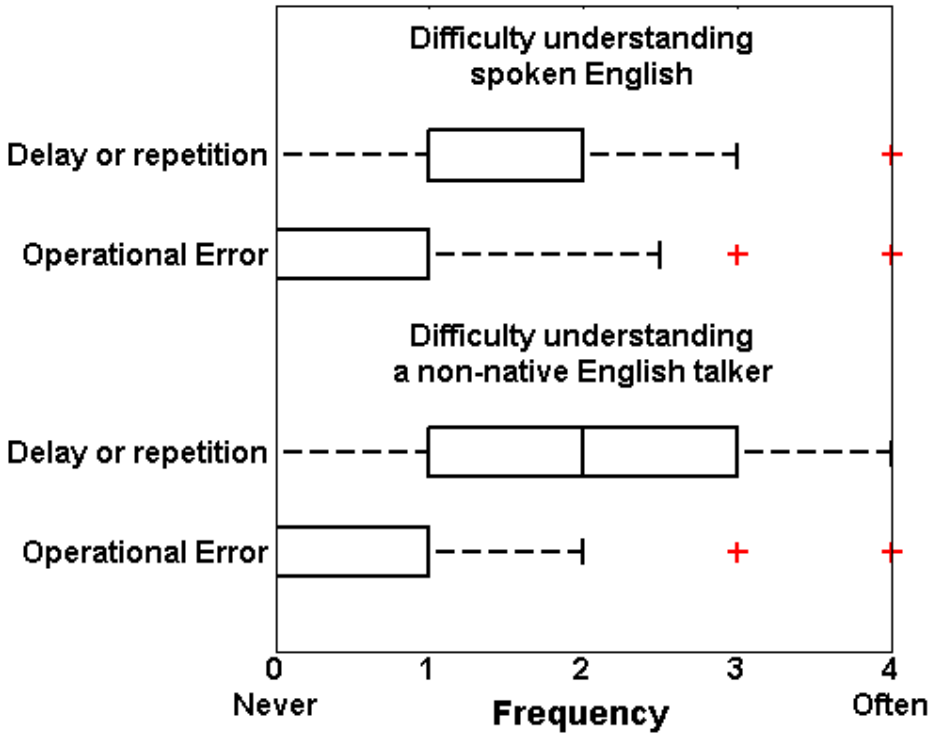
2. The difficulty of understanding a non-native English Talker?

A delay in communication or request for repetition (Never) 0 – 1 – 2 – 3 – 4 (Often)

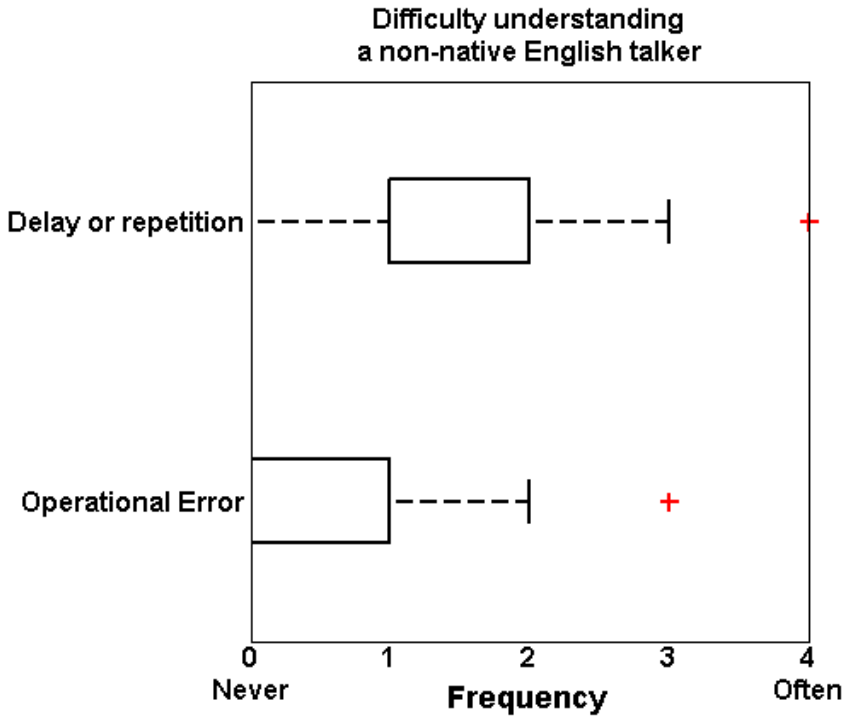
A misunderstanding leading to an operational error (Never) 0 – 1 – 2 – 3 – 4 (Often)

Delays and Errors

Non-Native English Subjects



Native English Subjects



Delays and Errors

'A Polish colleague mistaking the word "rations" for the word "Russians". As in, we have plenty of rations at our future location.'

'Assumption of information due to haste to complete conversation'

'Confusion over requirements leading to an operational delay'

'Delayed casualty transfer time'

'During a training mission, the whole class misunderstood my directions during an obstacle course and did the wrong sections.'

'During exercise, patients were not evacuated'

'Given poor clearance to fire.'

'Lack of understanding COM or chain of command's direction and guidance. Can lead to requirements for repetition, clarification or even misunderstan...'

'Misplanned mission - caught before impact to mission'

'Misunderstanding on direction and guidance leading to a sizeable amount of work being completed needlessly'

'Navigate to a point other than the specified one.'

'Sent out wrong aims sending NATO frigate into wrong direction'

'Serious delays in execution'

'The misunderstanding caused a 30 minute delay on starting/initiating the correct action'

Overall Goal

1) Develop standardized procedure for collecting speech samples

2) Obtain speech samples from multiple member nations

3) Conduct pilot study to evaluate interaction between English language proficiency and hearing loss

Progress to Date

We have developed a standardized system for collecting data

1) Nexus TAB-E android Tablet

2) Modified headset
(Includes microphone,
sound attenuation,
ability to add sidetone)

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Study Description

How many years of military service do you have?

Are you experiencing any problems with your voice today that might make you unusually difficult to understand?

What is your Native Language?

*Participant will select from a list of choices.

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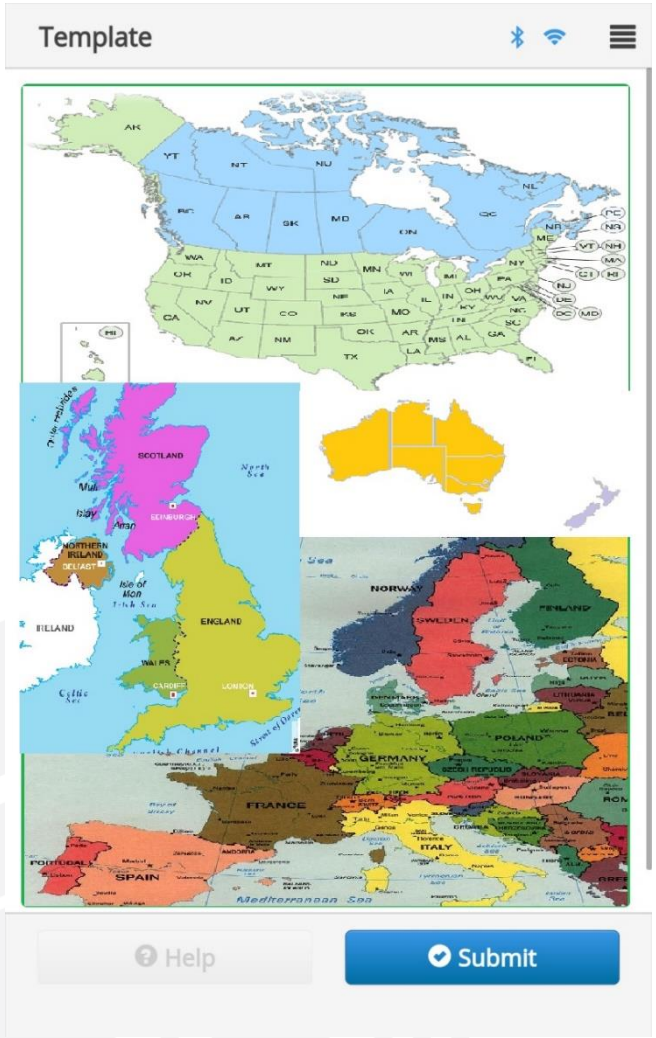
Study Description



What is your native region?

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Study Description

What is your English "STANAG" language level for Speaking?

What is your English "STANAG" language level for Listening Comprehension?

What is your English "STANAG" language level for Reading?

What is your English "STANAG" language level for Writing?

* Participant will select level from a scale of 0, meaning no proficiency, to 5, meaning highly-articulate native level.

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Study Description

English Language Test: OMT

Name	Verb	Number	Adjective	Noun	
Peter	got	three	large	desks	*Peter got three large desks.*
Kathy	sees	nine	small	chairs	*Kathy sees nine small chairs.*
Lucy	brought	seven	old	tables	*Lucy brought seven old tables.*
Alan	gives	eight	dark	toys	*Alan gives eight dark toys.*
Rachel	sold	four	heavy	spoons	*Rachel sold four heavy spoons.*
William	prefers	nineteen	green	windows	*William prefers nineteen green windows.*
Steven	has	two	cheap	sofas	*Steven has two cheap sofas.*
Thomas	kept	fifteen	pretty	rings	*Thomas kept fifteen pretty rings.*
Doris	ordered	twelve	red	flowers	*Doris ordered twelve red flowers.*
Nina	wants	sixty	white	houses	*Nina wants sixty white houses.*

Procedure

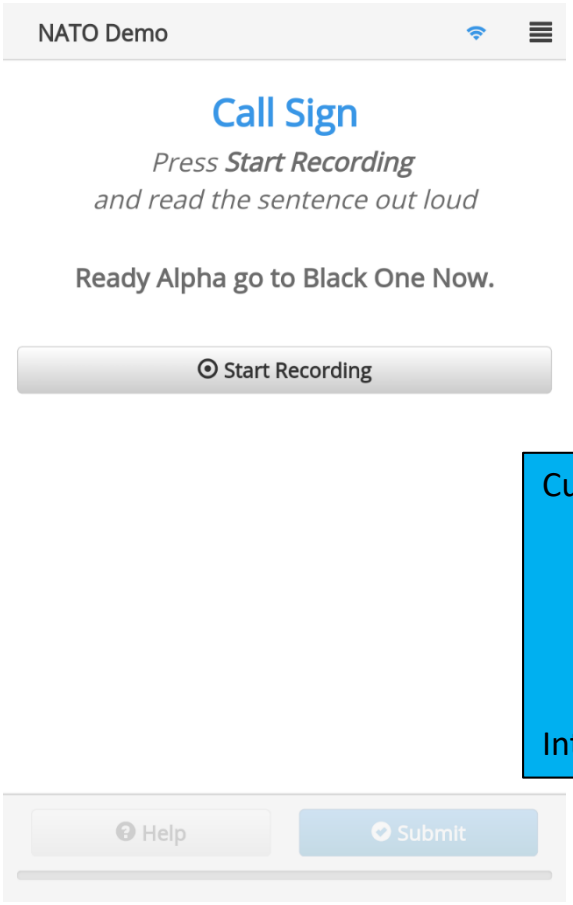
- Corpora Recordings
  - Participant will follow instructions using the TabSINT program to record stimuli.
  - To account for recordings being conducted in a variety of environments, a 65 dB SPL noise will be continuously presented through the headphones during the recording, and a sidetone will be present to reduce the Lombard effect by routing sound received by the microphone to the headphones.

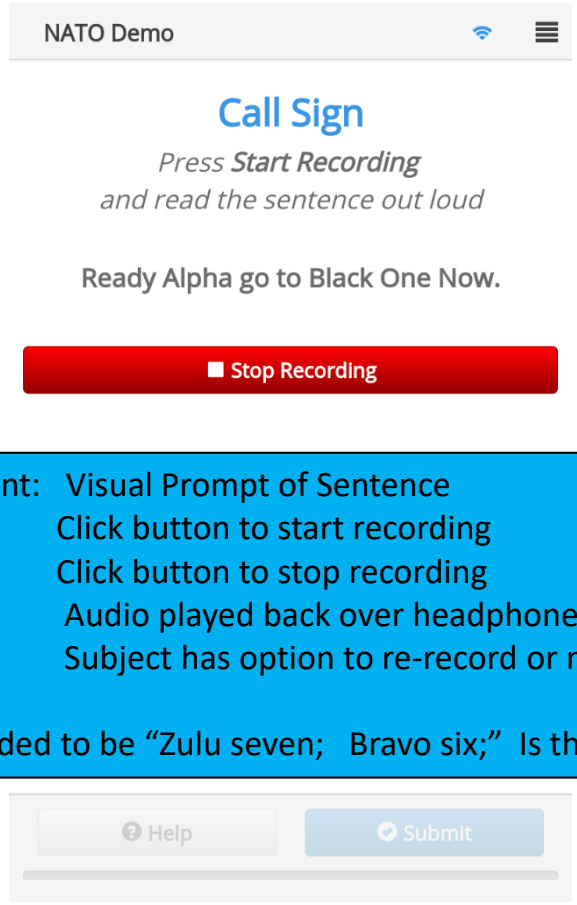
Corpora

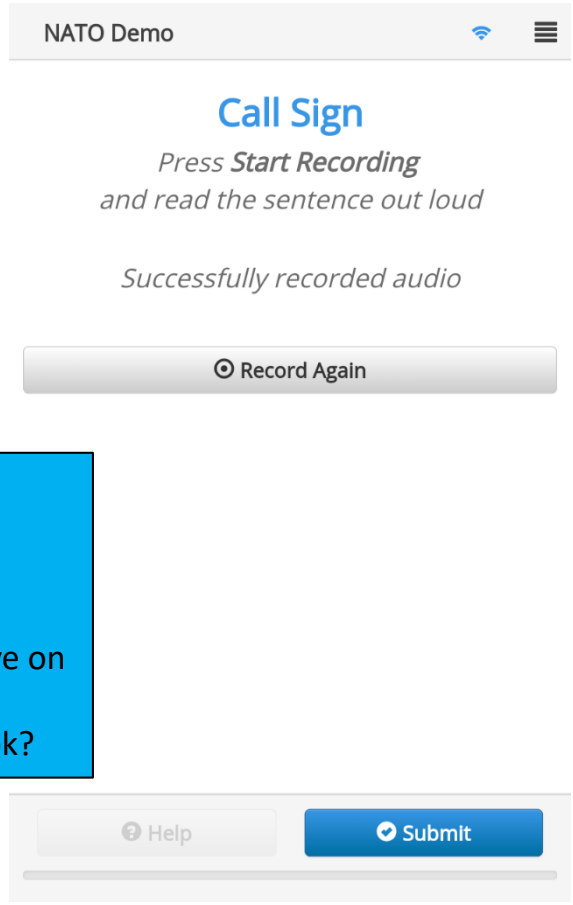
- NATO Call Sign/Number pairs
  - “Bravo Six”
  - “Zulu One”
  - “Kilo Three”

CHARACTER	MORSE CODE	TELEPHONY	PHONIC (PRONUNCIATION)
A	• —	Alfa	(AL-FAH)
B	— • • •	Bravo	(BRAH-VOH)
C	— • — •	Charlie	(CHAR-LEE) or (SHAR-LEE)
D	— • •	Delta	(DELL-TAH)
E	•	Echo	(ECK-OH)
F	• • — •	Foxtrot	(FOKS-TROT)
G	— — •	Golf	(GOLF)
H	• • • •	Hotel	(HOH-TEL)
I	• •	India	(IN-DEE-AH)
J	• — — —	Juliett	(JEW-LEE-ETT)
K	— • —	Kilo	(KEY-LOH)
L	• — • •	Lima	(LEE-MAH)
M	— —	Mike	(MIKE)
N	— •	November	(NO-VEM-BER)
O	— — —	Oscar	(OSS-CAH)
P	• — — •	Papa	(PAH-PAH)
Q	— — • —	Quebec	(KEH-BECK)
R	• — •	Romeo	(ROW-ME-OH)
S	• • •	Sierra	(SEE-AIR-RAH)
T	—	Tango	(TANG-GO)
U	• • —	Uniform	(YOU-NEE-FORM) or (OO-NEE-FORM)
V	• • • —	Victor	(VIK-TAH)
W	• — —	Whiskey	(WISS-KEY)
X	— • • —	Xray	(ECKS-RAY)
Y	— • — —	Yankee	(YANG-KEY)
Z	— — • •	Zulu	(ZOO-LOO)
1	• — — — —	One	(WUN)
2	• • — — —	Two	(TOO)
3	• • • — —	Three	(TREE)
4	• • • • —	Four	(FOW-ER)
5	• • • • •	Five	(FIFE)
6	— • • • •	Six	(SIX)
7	— — • • •	Seven	(SEV-EN)
8	— — — • •	Eight	(AIT)
9	— — — — •	Nine	(NIN-ER)
0	— — — — —	Zero	(ZEE-RO)

Recording – NATO Call Sign/Number Pairs







Current: Visual Prompt of Sentence
Click button to start recording
Click button to stop recording
Audio played back over headphones
Subject has option to re-record or move on

Intended to be “Zulu seven; Bravo six;” Is this ok?

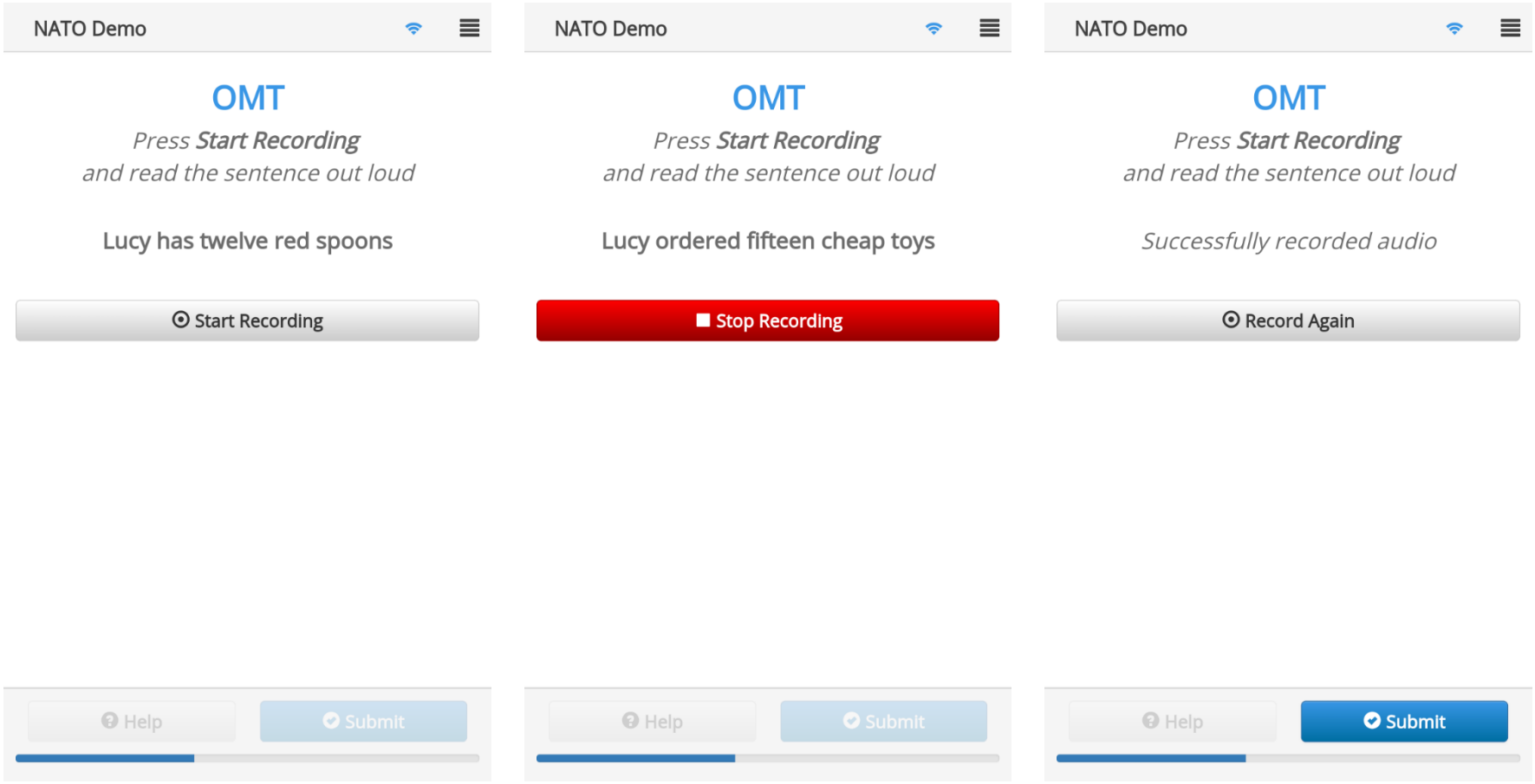
Corpora

- Matrix Test
  - Five key words include Name, Verb, Number, Adjective, and Noun.
    - “Steven has two cheap sofas”
  - This is available/under development in 20 languages.

Name	Verb	Number	Adjective	Noun	
Peter	got	three	large	desks	*Peter got three large desks.*
Kathy	sees	nine	small	chairs	*Kathy sees nine small chairs.*
Lucy	brought	seven	old	tables	*Lucy brought seven old tables.*
Alan	gives	eight	dark	toys	*Alan gives eight dark toys.*
Rachel	sold	four	heavy	spoons	*Rachel sold four heavy spoons.*
William	prefers	nineteen	green	windows	*William prefers nineteen green windows.*
Steven	has	two	cheap	sofas	*Steven has two cheap sofas.*
Thomas	kept	fifteen	pretty	rings	*Thomas kept fifteen pretty rings.*
Doris	ordered	twelve	red	flowers	*Doris ordered twelve red flowers.*
Nina	wants	sixty	white	houses	*Nina wants sixty white houses.*

Name	Verb	Number	Adjective	Noun	
Peter	bekommt	drei	große	Blumen	*Peter gets three big flowers.*
Kerstin	sieht	neun	kleine	Tassen	*Kerstin sees nine small cups.*
Tanja	kauft	sieben	alte	Autos	*Tanja buys seven old cars.*
Ulrich	gibt	acht	nasse	Bilder	*Ulrich gives eight wet pictures.*
Britta	schenkt	vier	schwere	Dosen	*Britta presents four heavy cans.*
Wolfgang	verleiht	fünf	grüne	Sessel	*Wolfgang lends five green armchairs.*
Stefan	hat	zwei	teure	Messer	*Stefan has two expensive knifes.*
Thomas	gewann	achtzehn	schöne	Schuhe	*Thomas won eighteen beautiful shoes.*
Doris	nahm	zwölf	rote	Steine	*Doris took twelve red stones.*
Nina	malt	elf	weiße	Ringe	*Nina paints eleven white rings.*

Oldenburg Matrix Sentences

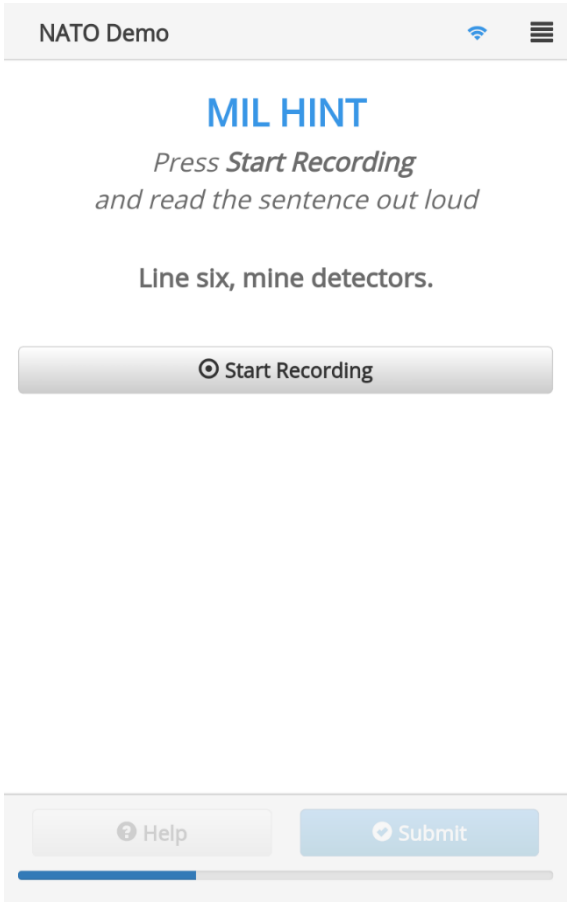


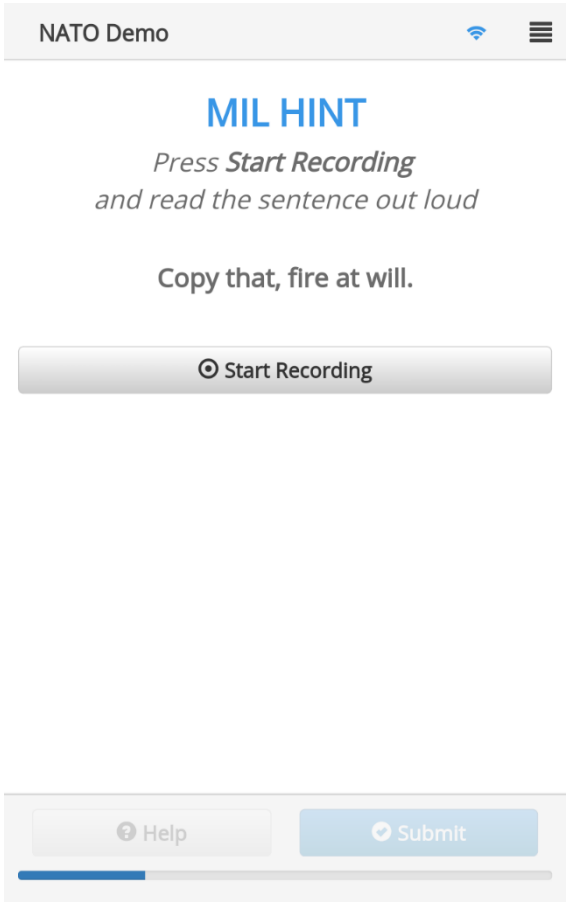
Corpora

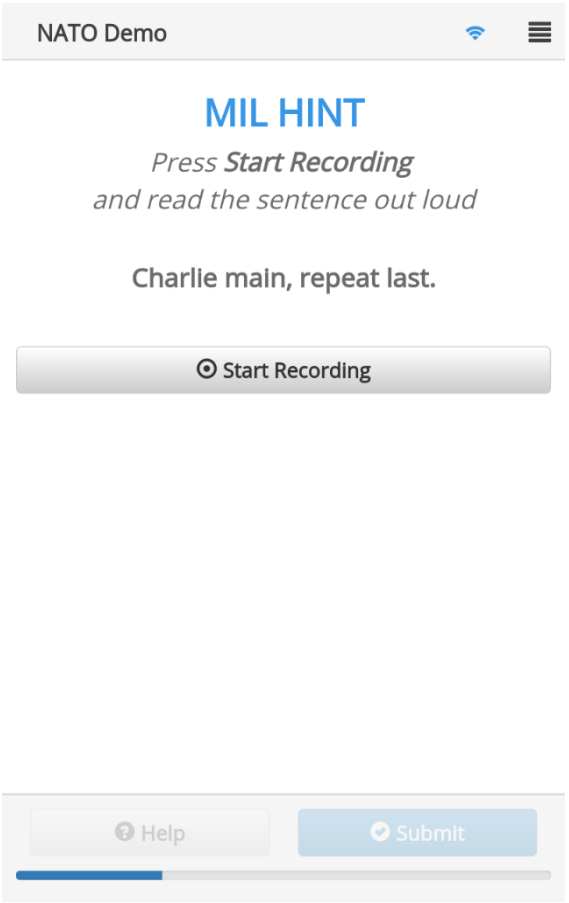
- Military Hearing in Noise Test (MILSINT)
  - Currently under development at University of Connecticut and Creare, Inc.
  - Speech-in-noise test that is designed to test active duty military personnel.

  - “Line Six, mine detectors.”
  - “Copy that, fire at will.”

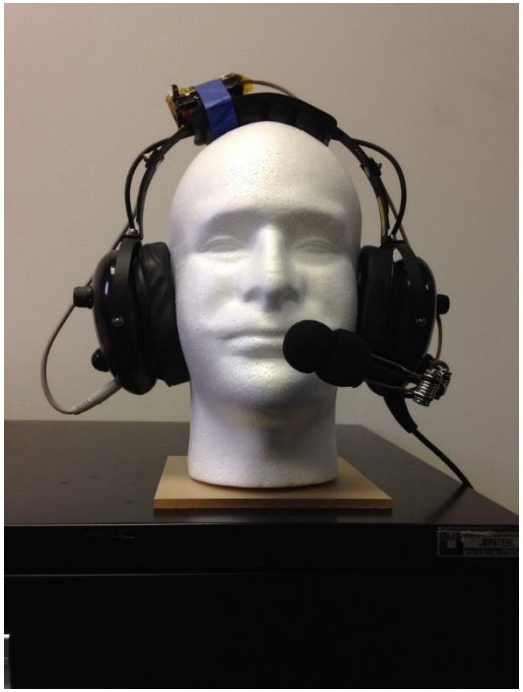
Military HINT Sentences







Customized Headphones



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Next Steps

Collect corpus on representative sample of NATO personnel
- Include multiple dialects of English

Test listeners with and without Hearing Loss on Corpus
- Control for voice effects versus language effects

Possible uses for training corpus

Possible uses for auditory display