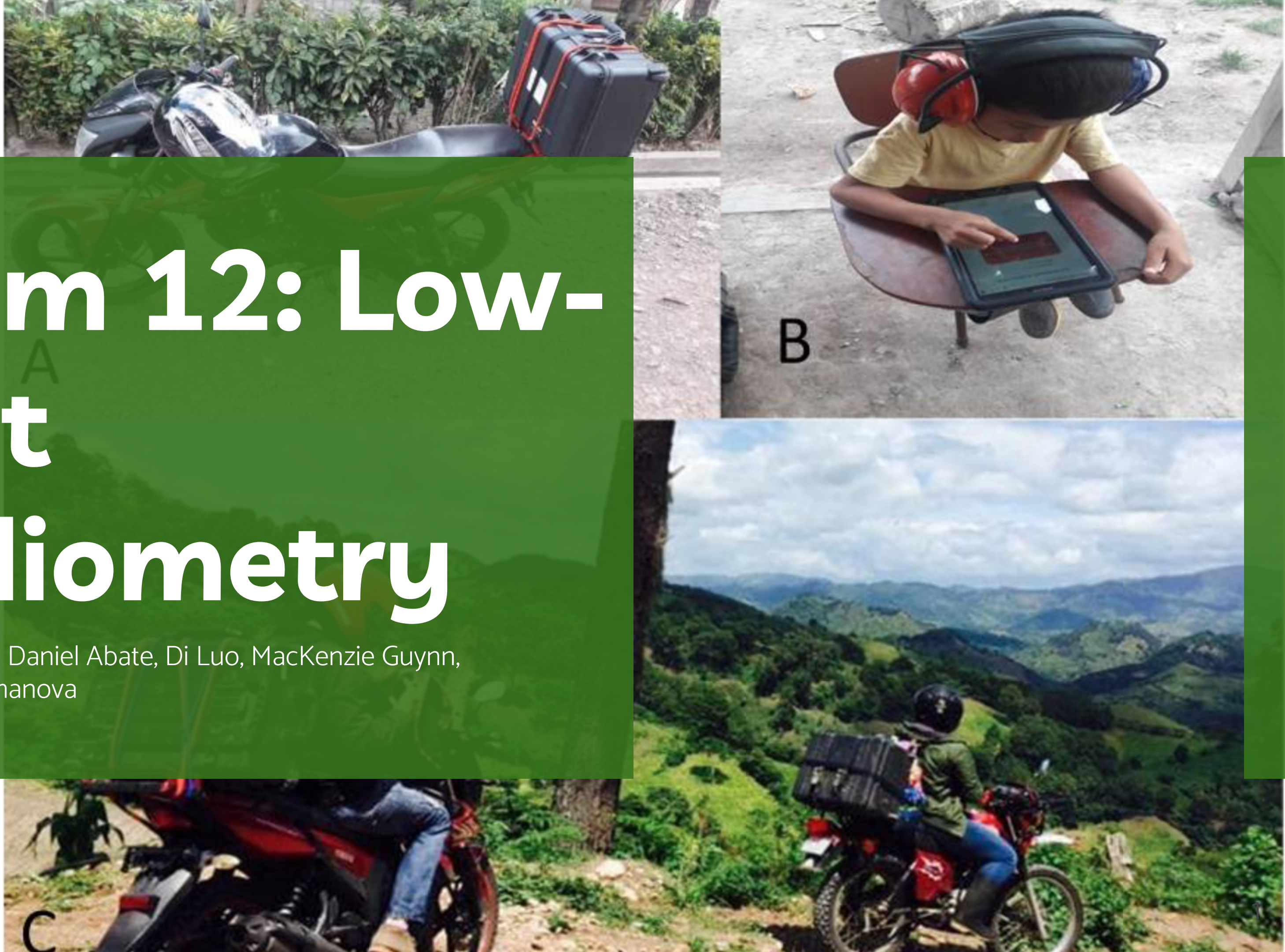
Team 12: Low-Cost Audiometry

Azariah Javillonar, Daniel Abate, Di Luo, MacKenzie Guynn, and Zhanel Nugmanova



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THAYER SCHOOL

THE STORY

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The Problem

Boothless audiometry is a technology that promises to increase access to hearing examinations in low-income regions. However, there is a need for the technology to be **cheaper, more informative, reliable, and easy-to-use** to aid audiologists in making more accurate and informed hearing loss diagnoses.

TECHNICAL TERMS

Sound Level Meter

Device for measuring the intensity of noise, music, and other sounds, consisting of a microphone, a preamplifier, signal, and processing.

Wireless Automated Hearing Test System (WAHTS)

System devised by Creare consisting of an audiometric headset, TabSINT software and sound level meter.

Audiometer

Device used to evaluate the hearing threshold of a person. An audiologist uses an audiometer to determine the hearing threshold and to quantify the degree of hearing loss of a person.

Transient Noise Spike

A spike can occur when the ambient noise passes a certain threshold. This can be due to conversations, children playing, animals, traffic, or a number of other things.

CURRENT SYSTEM

Svantek Dosimeter:
Meant to measure the sound exposure of one individual as well as the sound level of the general environment.

TabSINT:
Android Software which is used to administer hearing tests and analyze their results

Amplivox Audiocups:
Highly attenuating headset which delivers audiometry tones to the user.

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SOCIETAL CONTEXT

360M people worldwide experience mild to moderate levels of hearing loss

#1 most common birth defect is hearing loss

2x more likely for children born in low or middle-income countries to have hearing issues compared to infants born in wealthy states

SOCIETAL CONTEXT

Developmental delays

Poor educational outcomes

Employment market disadvantage

Cycle of economic disadvantage and poverty

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REQUIREMENTS & METRICS OF SUCCESS

Technical Requirements have been identified for the two main components of the solution where we shall be making changes:

1. Sound Level Meter
2. User Interface/User Experience

REQUIREMENTS & METRICS OF SUCCESS

1. SOUND LEVEL METER

- Need to confirm that the Tympan can function as a valid class 2 Sound Level Meter
- The standards are set forth by the **International Electrotechnical Commission (IEC)** in their document **IEC 61672-1:2013**
- The most noteworthy Performance Specifications are:
    a. Measurement tolerance/Acceptance Limits
    b. Frequency Response
    c. Level Linearity
    d. Self-Generated Noise (specify)
    e. Overload Indication (specify)

SOUND LEVEL METER SPECS

a) Measurement Tolerance/Acceptance Limits

Refers to the precision of sound level measurements made by the sound level meter at various frequencies.

Table 3 – Frequency weightings and acceptance limits

Nominal frequency Hz	Frequency weightings dB			Acceptance limits, dB Performance class	
	A	C	Z	1	2
10	-70,4	-14,3	0,0	+3,0; -∞	+5,0; -∞
12,5	-63,4	-11,2	0,0	+2,5; -∞	+5,0; -∞
16	-56,7	-8,5	0,0	+2,0; -4,0	+5,0; -∞
20	-50,5	-6,2	0,0	±2,0	±3,0
25	-44,7	-4,4	0,0	+2,0; -1,5	±3,0
31,5	-39,4	-3,0	0,0	±1,5	±3,0
40	-34,6	-2,0	0,0	±1,0	±2,0
50	-30,2	-1,3	0,0	±1,0	±2,0
63	-26,2	-0,8	0,0	±1,0	±2,0
80	-22,5	-0,5	0,0	±1,0	±2,0
100	-19,1	-0,3	0,0	±1,0	±1,5
125	-16,1	-0,2	0,0	±1,0	±1,5
160	-13,4	-0,1	0,0	±1,0	±1,5
200	-10,9	0,0	0,0	±1,0	±1,5
250	-8,6	0,0	0,0	±1,0	±1,5
315	-6,6	0,0	0,0	±1,0	±1,5
400	-4,8	0,0	0,0	±1,0	±1,5
500	-3,2	0,0	0,0	±1,0	±1,5
630	-1,9	0,0	0,0	±1,0	±1,5
800	-0,8	0,0	0,0	±1,0	±1,5
1 000	0	0	0	±0,7	±1,0
1 250	+0,6	0,0	0,0	±1,0	±1,5
1 600	+1,0	-0,1	0,0	±1,0	±2,0
2 000	+1,2	-0,2	0,0	±1,0	±2,0
2 500	+1,3	-0,3	0,0	±1,0	±2,5
3 150	+1,2	-0,5	0,0	±1,0	±2,5
4 000	+1,0	-0,8	0,0	±1,0	±3,0
5 000	+0,5	-1,3	0,0	±1,5	±3,5
6 300	-0,1	-2,0	0,0	+1,5; -2.0	±4,5
8 000	-1,1	-3,0	0,0	+1,5; -2,5	±5,0
10 000	-2,5	-4,4	0,0	+2,0; -3,0	+5,0; -∞
12 500	-4,3	-6,2	0,0	+2,0; -5,0	+5,0; -∞
16 000	-6,6	-8,5	0,0	+2,5; -16,0	+5,0; -∞
20 000	-9,3	-11,2	0,0	+3,0; -∞	+5,0; -∞

NOTE Frequency weightings were calculated by use of the analytical expressions in Annex E with frequency f computed from $f = f_r\,[10^{0,1(n-30)}]$ with f_r = 1 000 Hz and n an integer between 10 and 43. The weightings were rounded to a tenth of a decibel.

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SOUND LEVEL METER SPECS

b) Frequency Response

- Refers to the sensitivity of the sound level meter's microphone to sounds at different frequencies.
- According to the IEC 61672-1:13 , the microphone must be uniformly sensitive to at least the frequencies in the range of **31.5Hz to 8kHz**

SOUND LEVEL METER SPECS

c) Level Linearity

- The measured sound level on microphone should be a linear function of sound pressure on microphone
- IEC 61672-1:13 specifies that “Any 1 dB to 10 dB change in the level of the input signal shall cause the same change in the displayed sound level. **Measured deviations** from this design goal shall not exceed ±0.3 dB for class 1 and **±0.5 dB for class 2 sound level meters.**”

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SOUND LEVEL METER SPECS

d) Self-Generated Noise (specify)

- Contribution of internal electrical components to the sound level measured by the sound level meter.
- IEC 61672-1:13 states that this **value must be measured and recorded**. It shall be different for different mics used.

SOUND LEVEL METER SPECS

e) Acoustic Overload Indication

- Refers to the highest level of sound the meter can measure, within the specified distortion limit.
- This value is unique to the mic being used, and must be specified as per IEC 61672-1:13
- For our solution, we want to be able to measure up to **100 dB**

REQUIREMENTS & METRICS OF SUCCESS

2. USER INTERFACE/ USER EXPERIENCE

- This component of our solution lies within the TabSINT software
- In addition to displaying the test protocol, the UI also must display data on the **ambient noise level** as measured by the sound level meter. Aspects of the ambient noise level that will be displayed include:
  1. most recent noise level value
  2. mean noise level
  3. peak noise level
- Data will need to be reliably sent **without WiFi** access

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REQUIREMENTS & METRICS OF SUCCESS

2. USER INTERFACE/ USER EXPERIENCE

- An indicator of some sort will be used when ambient noise is too loud
- We will use ISO 8253 and WAHTS Standards to determine the threshold (MPANLs)

Frequency (Hz)	Ears uncovered† (dB SPL)	WAHTS attenuation (dB)	**WAHTS MPANLs (dB SPL)**
125	29	30.6	**59.6**
250	21	31.6	**52.6**
500	16	37.5	**53.5**
1000	13	39.5	**52.5**
2000	14	34.5	**48.5**
4000	11	36.0	**47.0**
8000	14	36.9	**50.9**

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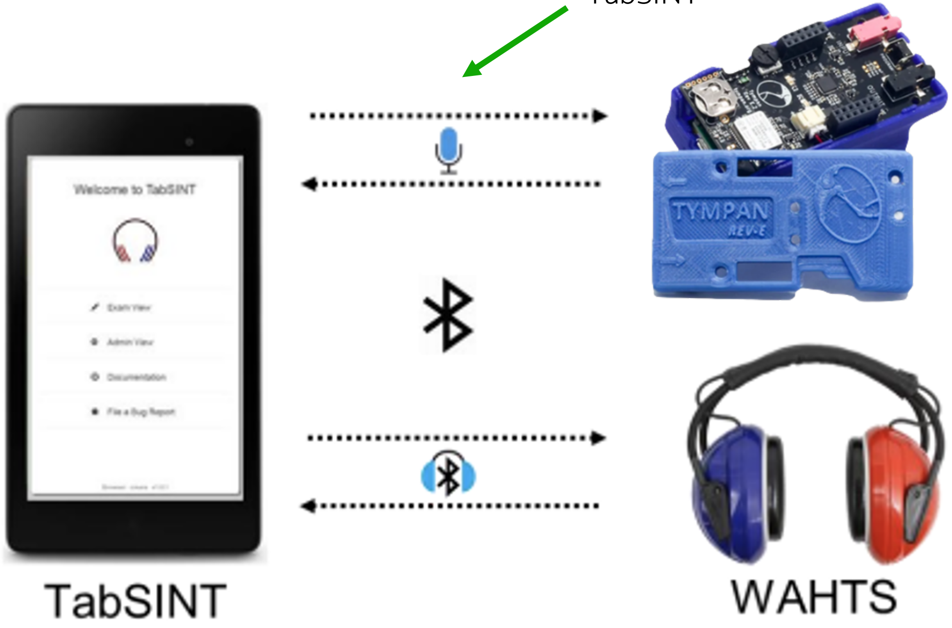
OUR PROPOSED SYSTEM

2. Adding a bluetooth connection between the Tympan and the TabSINT

Replacing Svantek Dosimeter with the Tympan as a SLM



3. Adding to the TabSINT software to include the SLM data in the exam and results pages

ENGS 90 FINAL DELIVERABLE

A fully-functioning WAHTS with the Tympan as the sound level meter, integrated with the TabSINT to display real-time ambient noise data in a helpful way.

Presented by:

1. A detailed report analyzing our system's performance in the field
2. A live demonstration

TYMPAN VALIDATION

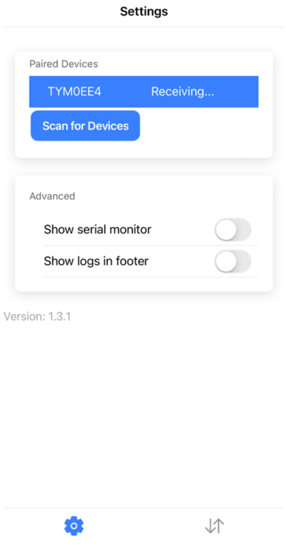
1. **Signal/Noise Ratio**
   a. **Self-generated noise**
2. **Frequency Response**
   a. **Level Linearity**
3. **Accuracy**
   a. **Acceptance Levels**

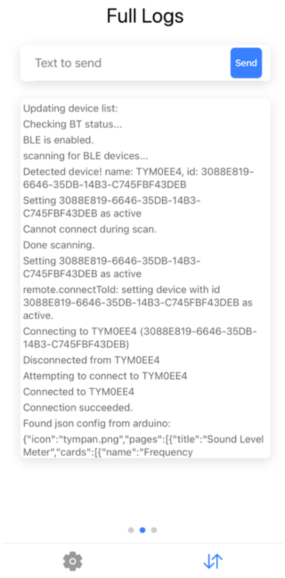
- All three tests will be conducted with the Tympan on-board microphone and an external micW microphone
  - The external microphone would increase the frequency range to between 20 Hz and 20 kHz
- Procedures are from the IEC standards
- Tests will be conducted at the DHMC lab with a soundproof booth, a class 1 sound level meter, and a tone generator

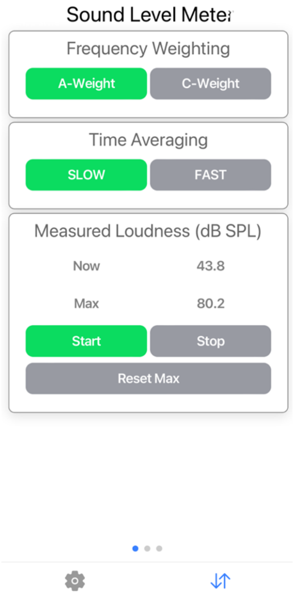
INTEGRATION OF TYMPAN AND TabSINT

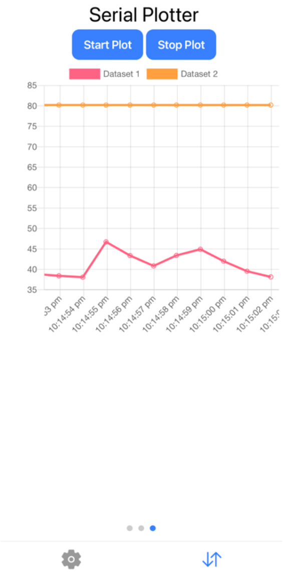
Related existing solutions:

1. TabSINT's connection with SV 104A
2. Tympan's connection with the TympanRemote App



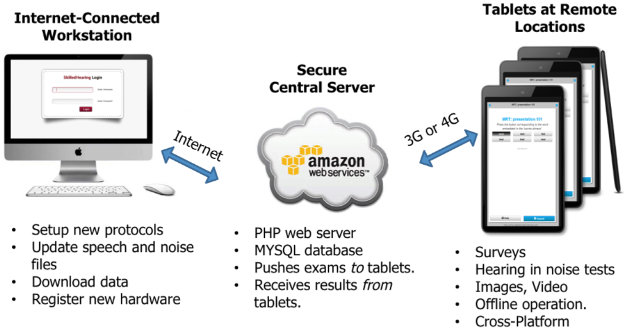




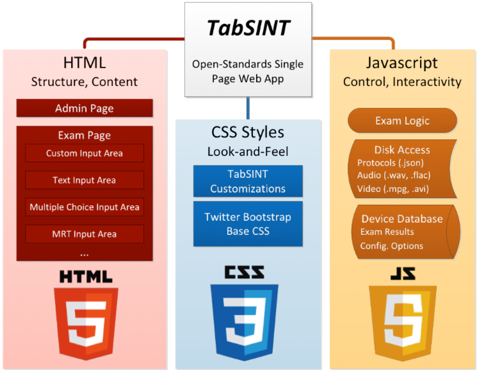


TabSINT SOFTWARE DEVELOPMENT

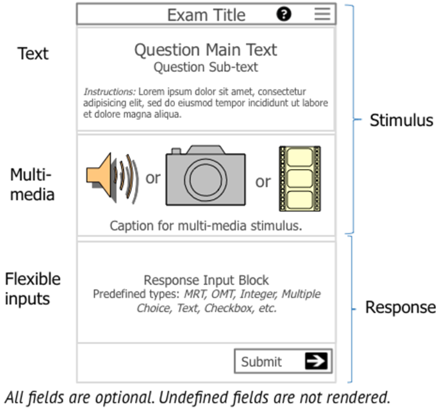
TabSINT Information:



Client-server Architecture



Standard Web Technologies



JSON Exam Page in Protocol

TabSINT SOFTWARE DEVELOPMENT

Project Characteristics:

1. Fixed time (end of ENGS 90)
2. Adding features to existing software instead of starting from the bottom
3. Dynamic scope (additional features might be implemented if time permitted)
4. Low burden in deployment or maintenance
5. Low documentation (only need documentation for newly implemented features)

Proposed Solution: **Agile** model with **Scrum** framework and **Kanban** methodology

Agile:

- Breaking tasks into smaller iterations
- Pre-defined but dynamic number of iterations, duration, scope of each iteration

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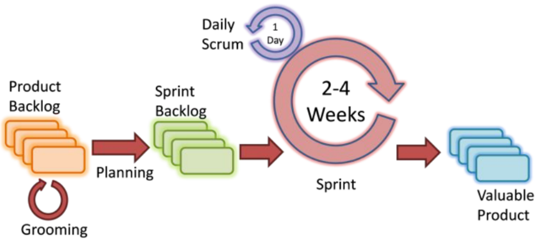
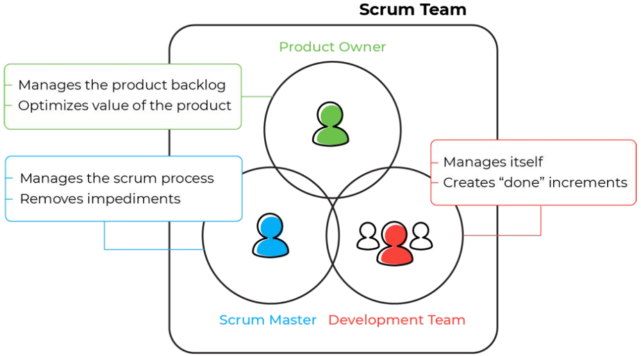
TabSINT SOFTWARE DEVELOPMENT

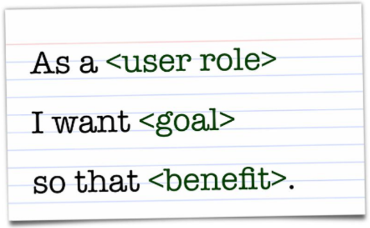
Scrum & Kanban:



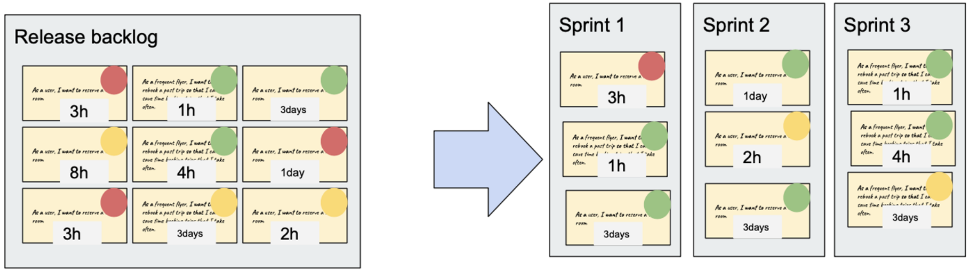
General Scrum Flow



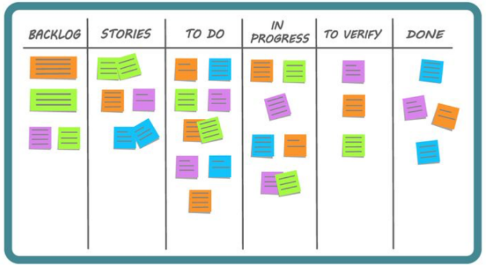
Breakdown of Scrum Team



User Story Template



Making Sprints from Product Backlog



Kanban

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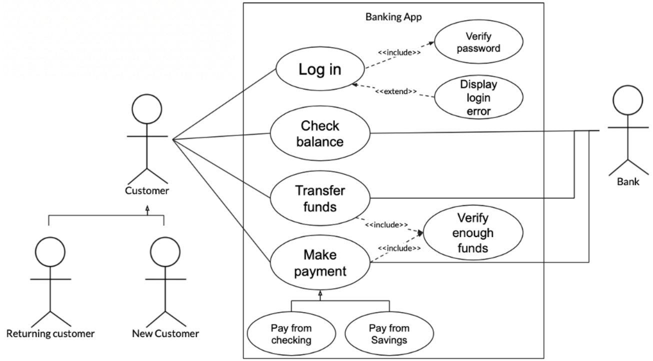
Proposed Solution: **Agile** model with **Scrum** framework and **Kanban** methodology

Other methodologies:

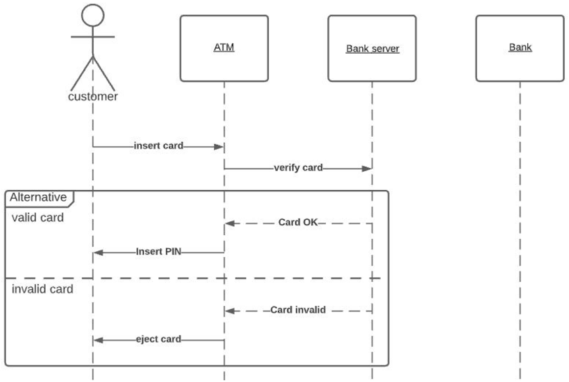
1. Unified Modeling Language (UML)

TabSINT SOFTWARE DEVELOPMENT

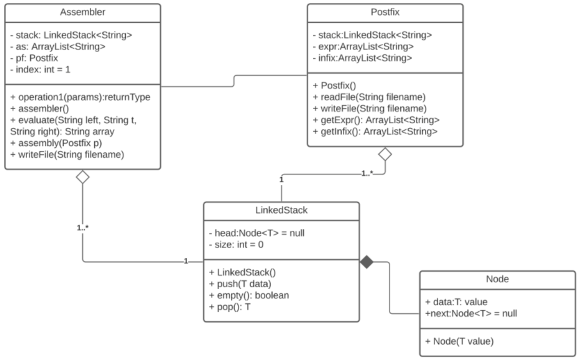
UML:



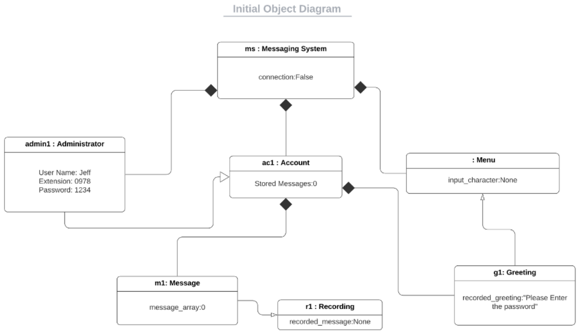
Use Case Diagram Example



Sequence Diagram Example



Class Diagram Example



Object Diagram Example

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Other methodologies:

1. Unified Modeling Language (UML)
2. Version Control: Git/GitHub/GitLab

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CUSTOMERS AND STAKEHOLDERS

Customers and Users:

- Doctors and research staff at DHMC
  - James E. Saunders (Audiology, hearing-related researches in Nicaragua)
  - Jay C. Buckey Jr (Audiology & hearing assessment, developing new audiological tests)
  - Christopher E. Niemczak (Research scientist)
  - Tori Lee (Research scientist)
- Healthcare workers and hospitals in underdeveloped communities
- Medical organizations (NGOs, etc.)
- Members of communities receiving boothless audiometry

Suppliers:

- Tympan.org (Hardware of Tympan)
- Manufacturers of microphone (Potential replacement of Tympan built-in microphones)

Competitor: Svantek (manufacturers of SOA microphones)

PARTNERS

Technical Partners at Creare LLC:

- Odile Clavier (Principle Engineer)
- Eric Yuan (Electrical Engineer, Tympan)
- Blaine Ayotte (Software Engineer, TabSINT)
- Chip Audette (Research Engineer)
- Joel Murphy (Hardware Engineer)

Dartmouth Resources:

- Academic
  - Peter Chin (Faculty advisor, signal processing)
  - Laura Ray (Signal processing)
  - Nikki Stevens (UI adviser)
- Administrative
  - Solomon Diamond
  - Emily Monroe
  - Rafe Steinhauer

Others:

- Contributors to Tympan and TabSINT

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Competitor Landscape & Specifications Comparison

SLM	Cost	Works off-line	Integratable with TabSINT	Open Source	Weighting Filters	Frequency Range	Additional In-built Features
Svantek 104a	>$500 ($2,568)	Yes	Yes	No	A, C, and Z	20 Hz - 20 kHz	1. Shock resistance & shock detection via inbuilt tri-axial accelerometer 2. Auto-calibration (comes with calibrator, SV 34)
Tympan	<$500 ($299)	Yes	Yes	Yes	A, C, and Z	10 Hz - 10 kHz*	No

*Frequency Range increases to 20 Hz - 20 kHz with an external microphone

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RISK SEVERITY MATRIX

Likelihood	Harm Severity			
	Negligible	Marginal	Critical	Catastrophic
Certain				
Likely		Change in software requirements		
Possible		Validation failure	Overtime	
Unlikely	Over budget		Integration failure	
Rare				

DE-RISKING: TYMPAN VALIDATION

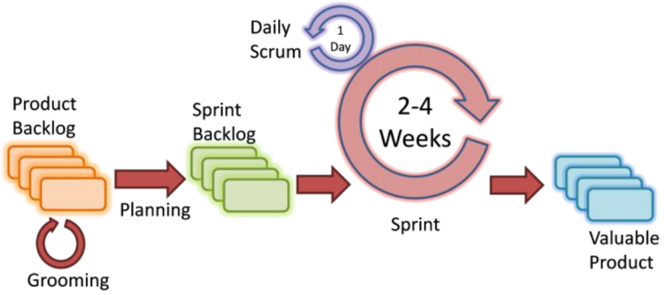
- Overtime
  - Prioritizing validation
  - Following IEC Standards for classification and testing protocols
- Failure
  - If we validate that the Tympan is appropriate, we can move on to the second stage of our solution
  - If the Tympan does not meet our requirements, we will need to look for a better solution
    - A new microphone
    - Re-evaluate our metrics of success

We will be conducting our initial tests on Thursday!

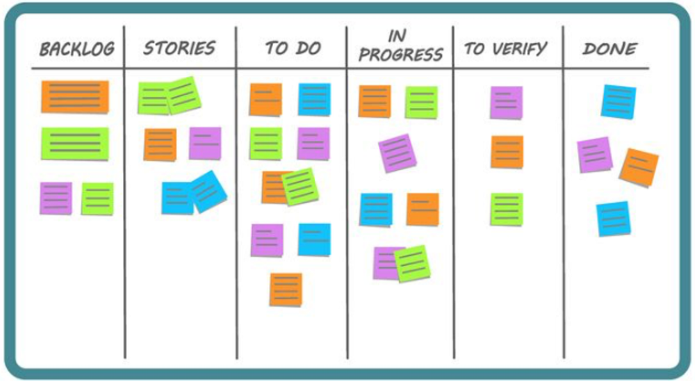
DE-RISKING:
OVERTIME & CHANGE IN SOFTWARE REQUIREMENTS

TabSINT Development:

- Scrum



- Kanban



DE-RISKING:
OVERTIME & CHANGE IN SOFTWARE REQUIREMENTS

TabSINT Development:

	Sprint	Story or Task	Epic	Type	Description	Stage
7		Product Backlog				
8	Backlog	Backlog				
9	Backlog	Integrate Tympan into TabSINT		Story	As a doctor, I want to have Tympan incorporated into the system, so that I don't have to deal with two pieces of software.	
14	Backlog	Display noise level data in exam page		Story	As a research assistant, I want to see noise measurement data on the screen while conducting manual audiometry, so that I can monitor the noise level and rerun the exam when there is a transient noise spike.	Goes after "Integrate Tympan into TabSINT."
18	Backlog	Automatically pause after noise spike		Story	As research assistants and doctors, we want to pause the exam automatically when a transient noise spike is detected, so that in manual audiometry we don't need to pay too much attention to noise level and in automated audiometry the participant doesn't need any extra action when there is a noise spike.	Goes after "Integrate Tympan into TabSINT."
23	Backlog	Restart the current test after pause		Story	As research assistants and doctors, we want to redo the current test after the pause, so that we don't need to manually select the test that runs next.	Goes after "Automatically pause after noise spike."
28	Backlog	Option to abort interfered results		Story	As a doctor, I want to give technicians the option to abort an automated test if the child was too interested in the button or there are transient noise spikes, so that invalid results are not stored.	
32	Backlog	Pre-test on noise level		Story	As a doctor, I want to run a pre-test at the beginning of the audiometry to see ambient noise, so that the audiometry only continues when the noise level is acceptable.	
36	Backlog	Store Tympan results		Story	As a doctor, I want to store max levels of noise or averages across the test period, when the spikes occurred, and how large the spikes were, so that I can examine the data after the audiometry.	
41	Backlog	Plot ambient sound level in exam pages		Story	As a research assistant, I want to have a plot of ambient sound level during manual audiometry, so that health workers can see the noise levels intuitively and act accordingly to the noise level.	
47	Backlog	Automate Tympan's start/end recording		Story	As a research assistant, I want to automate Tympan's start and end recoding so that Tympan starts recording after pressing "Go" and stops recoding when the test ends.	
52	Backlog	Stop measuring when participant talks		Story	As a research assistant, I want to include a button that could be pressed to ignore following ambient noise when doing the tests that require the participant to repeat the sentence they heard back to them, so that the voice of the participants doesn't influence the test.	Goes after the implementation of remote control of Tympan.

DE-RISKING:
OVERTIME & CHANGE IN SOFTWARE REQUIREMENTS

TabSINT Development:

	Sprint	Story or Task	Epic	Type	Description	Stage
41	Backlog	Plot ambient sound level in exam pages		Story	As a research assistant, I want to have a plot of ambient sound level during manual audiometry, so that health workers can see the noise levels intuitively and act accordingly to the noise level.	
42	Backlog	Add "Display plot" option to protocol		Task	On the first page of the protocol, the health worker can choose whether to display the ambient sound level plot or not with a option button.	
43	Backlog	Determine the location of plot		Task	Determine on which part of the exam page the plot is displayed. Temporary options are: in the "Show debug info" dropdown list, right below the response area of exam pages, etc.	
44	Backlog	Interface of the plot		Task	Determine what data to be displayed on the plot. Design the appearance of the plot such as the axis names, plot type (line? bar?), etc.	
45	Backlog	Refreshing the plot		Task	Implement the refreshing of the plot after each specified time period (e.g. 1 second).	
46	Backlog	Testing		Task	Integrate the plot into current system and test	

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DE-RISKING:
OVERTIME & CHANGE IN SOFTWARE REQUIREMENTS

TabSINT Development:

Sprint 1 (R1) (3)

Backlog
Integrate Tympan into TabSINT
Story
As a doctor, I want to have ...
4

Backlog
Display noise data in exam page
Story
As a research assistant, I w...
3

Backlog
Automate Tympan's start & end recording
Story
As a research assistant, I w...
4

Sprint 2 (R1) (4)

Backlog
Automatically pause after noise spike
Story
As research assistants and ...
4

Backlog
Restart the current test aft... pause
Story
As research assistants and ...
4

Backlog
Plot ambient sound level in exam pages
Story
As a research assistant, I w...
5

Backlog
Store Tympan results
Story
As a doctor, I want to store ...
4

Sprint 3 (R1) (3)

Backlog
Add option to abort interfered results
Story
As a doctor, I want to give t...
3

Backlog
Pre-test on noise level
Story
As a doctor, I want to run a ...
3

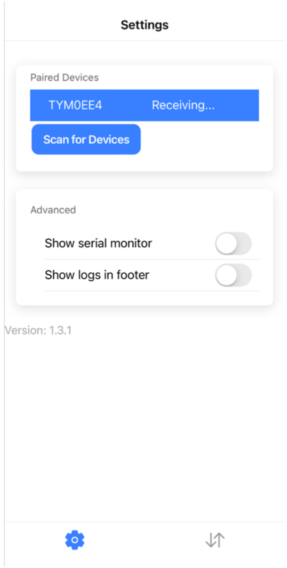
Backlog
Stop measuring when participant talks
Story
As a research assistant, I w...
4

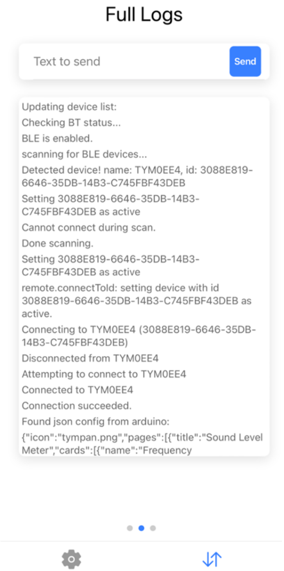
Others:

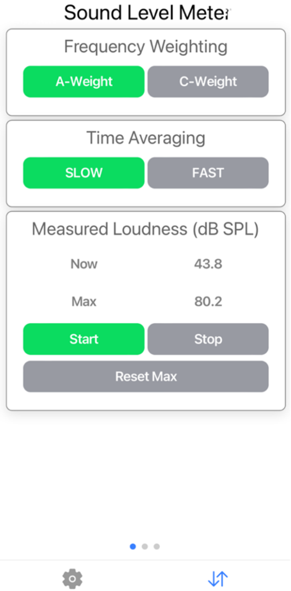
- Programming languages
- Development Environment

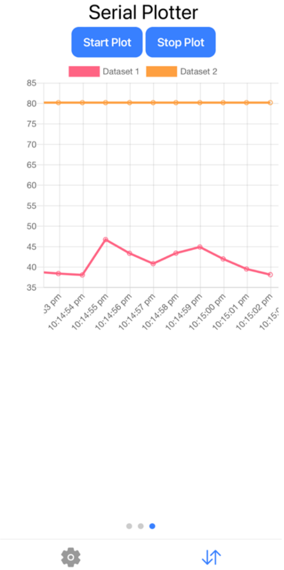
DE-RISKING: INTEGRATION FAILURE

- TabSINT's connection with SV 104A
- Tympan's connection with the TympanRemote App









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STAKEHOLDER ENGAGEMENT

Doctors at DHMC

Dr. Saunders, Dr. Buckey, Chris Niemczak, and Torri Lee

- Conducting tests in the lab's soundproof booth with their SLM and tone generator
- Initial interviews as users of the system to identify problems
- Continued interviews to add concrete user stories to our backlog
- Were given a partial hearing test to better understand the system from the patient's perspective
- Loaned us an Android tablet and WAHTS headset for our development

Engineers at Creare and Tympan

Odile Clavier, Blaine Ayotte, Eric Yuan, Chip Audette, and Joel Murphy

- Received previous validation procedures and results for the Tympan
- Verified that our thought processes for Tympan development aligned with their experiences
- Overcoming obstacles in terms of TabSINT setup and programming
- Interviews to identify the open-source developer perspective as we begin development

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ECONOMIC ANALYSIS

$299 **Cost of the Tympan Rev E**
Supplied by Tympan

$129 **Cost of the i43 external microphone**
Supplied by micW

$428 **Total Cost for our solution**

This matches our stakeholders' ideal cost of under $500 dollars.

The rest of the system will not be changed, so existing components can be used with our additions and won't incur an additional cost.

It is also important to note that these are capital costs, and should have minimal operating costs.

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OUR TEAM

Azariah Javillonar

- Computer Engineer with a focus in computer architecture and operating systems

Di Luo

- Computer Science major at Colby College
- Computer Engineering at Thayer

Daniel Abate

- Electrical Engineer with a focus in signal processing
- Internship experience in Software engineering

MacKenzie Guynn

- Electrical Engineer with a focus in firmware development
- Computer Science minor

Zhanel Nugmanova

- Biomedical Engineer
- Computer Science minor

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OUR RESOURCES

Professor Peter Chin

- Signal Processing Expert

Nikki Stevens

- Software engineer with open-source experience

ENGS 89 Teaching Staff

- Guidance on our general goals

- Odile Clavier, Eric Yuan, Blaine Ayotte, Chip Audette, and Joel Murphy
- Provide technical advice on Tympan and TabSINT development

- Dr. Buckey, Dr. Saunders, Chris Niemczak, and Torri Lee
- Offer first-hand accounts of the current system
- Provide tools needed for hardware validation

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TIMELINE

	ENGS 89			ENGS 90										
	Week 8-9 10/31 - 11/11	Week 10 11/14 - 11/18	Winterim 11/21 - 1/4	Week 1 1/4-1/7	Week 2 1/11 - 1/14	Week 3 1/18 - 1/21	Week 4 1/25 - 1/28	Week 5 2/1 - 2/4	Week 6 2/8 - 2/11	Week 7 2/15 - 2/18	Week 8 2/22 - 2/25	Week 9 3/1 - 3/4	Week 10 3/8 - 3/11
Presentations														
Proposal														
Progress Report														
Final Report and Demonstration														
Preliminary research														
Development of validation tests for the Tympan and external mic														
Tympan to TabSINT connection research														
Familiarize ourselves with TabSINT and Tympan software														
Creare Technical Meetings														
UI design conceptualization														
Tympan to TabSINT Integration														
Tympan - Connect to mobile app and run examples														
Tympan - Test the noise floor of the internal and external mics														
Tympan - Test the frequency response of both mics														
Tympan - Test the accuracy of the Tympan as a SLM with both mics														
Tympan - Determine the best mic to be used for a SLM														
Study connection between TabSINT and SV104A														
Study connection between Tympan and TympanRemoteApp														
Connect Tympan and TabSINT via Bluetoooth														
Test the Tympan and TabSINT connection														
TabSINT Software Development														
Collect all user stories into product backlog														
Setup development environment of TabSINT on local computers														
Study related programming languages														
Analyze product backlog and setup Scrum sprints														
Sprint 1														
Sprint 2														
Sprint 3														
Full System Testing														
Get CPHS trained and approved for testing														
Finalize a protocol with the DHMC doctors														
Submit a protocol for approval														
Find a pool of participants to conduct user testing on														
Modifications based on user testing														

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OUTLOOK

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OUTLOOK

Final Deliverable: A live demonstration of the fully functional and updated version of the WAHTS

a. Tympan integrated into TabSINT software as a valid SLM
    i. The results of each validation test
b. The most effective UI shown in the demonstration
c. A detailed report of our system being used in the field

Thank You!
Questions?

MAIN SOURCES SUPPORTING PROBLEM DEFINITION

Mobile Smartphone Audiometry to Improve Hearing Outcomes in Nicaraguan Children

Saunders, James E.

Dartmouth College, Hanover, NH, United States

Abstract

Approximately 360 million people worldwide have disabling hearing loss and the vast majority live in Low and Middle Income Countries (LMIC) were services are scarce. Hearing loss is the most common birth defect and many cases of childhood hearing loss in LMIC are related to untreated ear infections. Unfortunately, many cases of pediatric hearing loss are unrecognized. Many of these children will suffer from poor language development, educational outcomes, and employment opportunities if the hearing loss is untreated. School hearing screening in LIMC is challenging due to high background noise in these environments and the lack of trained personnel. Preliminary research in rural Nicaragua suggests that 27% of schoolchildren fail initial hearing screening exams, but poor quality screening exams from high ambient noise levels lead to a presumed high rate of unnecessary referrals. Less than 10% of these children ever receive further evaluation or treatment. Mobile health techniques that provide early and accurate recognition of childhood hearing loss, combined with a reminder system for appointments, could improve the outcomes from hearing screening efforts. This project combines a team experienced in hearing testing in both rural Nicaragua and Tanzania (Saunders, Buckey) with an innovative noise attenuating-wireless headset with direct mobile communication (via cell phone or internet). Creare, LLC has developed a hearing threshold screening device that performs automated audiometry, is controlled through a mobile platform, and provides superior background noise attenuation using innovative, integrated, high-quality, noise-attenuating ear cups. This technology can also communicate directly with a mobile health network to facilitate initial management and follow up appointments. This project will demonstrate that minimally-trained personnel can use mobile-health-technology-based hearing screening to perform high-quality audiometry on Nicaraguan school children in their schools. The efficacy of this mobile-health-technology-based system will then be investigated in a large-scale study of schoolchildren in rural communities throughout Jinotega.

NIH National Library of Medicine
National Center for Biotechnology Information

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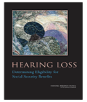

Hearing Loss: Determining Eligibility for Social Security Benefits.

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Appendix B American National Standards on Acoustics

The content of each of ten standards of the American National Standards Institute (ANSI) pertaining to bioacoustics (S3) and referenced in this report is briefly described here. The standards can be obtained from the Acoustical Society of America (ASA), Standards Secretariat, 35 Pinelawn Rd., Suite 114E, Melville, NY 11747, or https://asastore.aip.org/ (under S3 Bioacoustics).

ANSI S3.1-1999 (R2003) *American National Standard Maximum Permissible Ambient Noise Levels for Audiometric Test Rooms.* This Standard specifies maximum permissible ambient noise levels (MPANLs) allowed in an audiometric test room that produce negligible masking (less than or equal to 2 dB) of test signals presented at reference equivalent threshold levels specified in American National Standard S3.6-1996 American National Standard Specification of Audiometers. The MPANLs are specified from 125 to 8000 Hz in octave and one-third octave band intervals for two audiometric testing conditions (ears covered and ears not covered) and for three test frequency ranges (125 to 8000 Hz, 250 to 8000 Hz, and 500 to 8000 Hz). The Standard is intended for use by all persons testing hearing and for distributors, installers, designers, and manufacturers of audiometric testrooms. This standard is a revision of ANSI S3.1-1991 American National Standard Maximum Permissible Ambient Noise Levels for Audiometric Test Rooms

ANSI S3.4-1980 (R2003) *American National Standard Procedure for the Computation of Loudness of Noise.* This standard specifies a procedure for calculating the loudness of certain classes of noise. In applications of the procedure, it is assumed that the spectrum of the sound has been measured in terms of sound pressure levels in 1/3-octave or 1/1-octave bands in either a diffuse or free field. The procedure is derived from three empirical relations: (1) A set of

TYMPAN TO TABSINT CONNECTION

Based on conversations with stakeholders, the information about the ambient noise that could be sent includes:

1. Mean Noise Level over the test
2. Max Noise Level over the test
3. Transient Noise Peaks and when they occurred
4. Which tones were impacted by the transient noise peaks
5. A red, yellow, green indicator about how the ambient noise will interfere with the test
6. The type of weighting used in the meter

Based on these data points, the following can be reported:

1. Whether the test was reliable or not
2. Which frequencies should be repeated in a new test
3. Whether the test protocol should be altered at any point
4. A plot of hearing test results with ambient noise levels

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Points for Further Clarification

General

1. Look into ANSI Recommendations for Boothless Audiometry, Sound Booths, and Classrooms to find the best way to determine ranges for “Green, Yellow, and Red.”
2. How can we reduce the amount of training needed to help with the shortage of trained audiologists in developing countries?

Review Board

1. Given that we were presented with the Tympan as a solution, did you notice any blind spots in our analysis?
2. Any tips on how to validate the Tympan? Are you aware of any Dartmouth resources to help?
3. Based on our presentation, which aspect of this project should we devote the most focus to?

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Sources

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9359107/

https://svantek.com/products/sv-104a-personal-noise-dosimeter/

https://www.reuters.com/article/us-hearing-healthcare/one-in-three-u-s-adults-with-hearing-problems-dont-seek-help-idUSKBN1DS2TZ

https://www.tandfonline.com/doi/full/10.1080/14992027.2021.1883197

https://svantek.com/products/sv-104a-personal-noise-dosimeter/

https://shop.tympan.org/products/tympan-rev-e

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Appendix A: Hearing Test Procedure

Manual:

- The WAHTS headphones are placed on the child's head.
- A technician begins recording ambient noise with the sound level meter.
- The technician determines the frequency of each tone, and when to administer it.
  - They can "pause" the test if they sense a spike
- The child will be asked to indicate when they hear the tone by raising their hand.
- Once the test is complete, the technician will receive the mean ambient sound level.

Autonomous:

- The WAHTS headphones are placed on the child's head.
- A technician begins recording ambient noise with the sound level meter.
- The audiometry system determines which frequency to deliver and when to administer it.
- The child is asked to press the button on the tablet when they hear the tone.
  - This has lead to problems in the past with the child pressing the button prematurely out of curiosity

SOUND LEVEL METER SPECS

d) Toneburst Response

- Refers to the sound level measurement made by the meter in response to a 4 kHz toneburst of various durations

Table 4 – Reference 4 kHz toneburst responses and acceptance limits

Toneburst duration, T_b ms	Reference 4 kHz toneburst response, δ_{ref}, relative to the steady sound level dB		Acceptance limits dB	
			Performance class	
	$L_{AFmax} - L_A$ $L_{CFmax} - L_C$ and $L_{ZFmax} - L_Z$; Eq. (7)	$L_{AE} - L_A$ $L_{CE} - L_C$ and $L_{ZE} - L_Z$; Eq. (8)	1	2
1 000	0,0	0,0	±0,5	±1,0
500	-0,1	-3,0	±0,5	±1,0
200	-1,0	-7,0	±0,5	±1,0
100	-2,6	-10,0	±1,0	±1,0
50	-4,8	-13,0	±1,0	+1,0; -1,5
20	-8,3	-17,0	±1,0	+1,0; -2,0
10	-11,1	-20,0	±1,0	+1,0; -2,0
5	-14,1	-23,0	±1,0	+1,0; -2,5
2	-18,0	-27,0	+1,0; -1,5	+1,0; -2,5
1	-21,0	-30,0	+1,0; -2,0	+1,0; -3,0
0,5	-24,0	-33,0	+1,0; -2,5	+1,0; -4,0
0,25	-27,0	-36,0	+1,0; -3,0	+1,5; -5,0
	$L_{ASmax} - L_A$ $L_{CSmax} - L_C$ and $L_{ZSmax} - L_Z$; Eq. (7)			
1 000	-2,0		±0,5	±1,0
500	-4,1		±0,5	±1,0
200	-7,4		±0,5	±1,0
100	-10,2		±1,0	±1,0
50	-13,1		±1,0	+1,0; -1,5
20	-17,0		+1,0; -1,5	+1,0; -2,0
10	-20,0		+1,0; -2,0	+1,0; -3,0
5	-23,0		+1,0; -2,5	+1,0; -4,0
2	-27,0		+1,0; -3,0	+1,0; -5,0

SOUND LEVEL METER SPECS

c) Directional Response

- Refers to how the meter's mic responds to sound coming from different directions. Ideally, response should be the same from all directions.

Table 2 – Acceptance limits for deviations of directional response from the design goal

Frequency kHz	Maximum absolute value of the difference between displayed sound levels at any two sound-incidence angles within ±θ degrees from the reference direction dB					
	θ = 30°		θ = 90°		θ = 150°	
	Performance class					
	1	2	1	2	1	2
0,25 to 1	1,0	2,0	1,5	3,0	2,0	5,0
>1 to 2	1,0	2,0	2,0	4,0	4,0	7,0
>2 to 4	1,5	4,0	4,0	7,0	6,0	12,0
>4 to 8	2,5	6,0	7,0	12,0	10,0	16,0
>8 to 12,5	4,0	...	10,0	...	14,0	...

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