Verification and Validation Report: SE 4G06, TRON 4TB6

Team 26, STRONE
Jordan Bierbrier
Azriel Gingoyon
Taranjit Lotey
Udeep Shah
Abraham Taha

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Revision History

Date	Version	Notes
3/7/2023	1.0	Added Section 1, 2, and 3 - Purpose, Scope, and Background
3/7/2023	1.1	Added Section 4 - Functional Requirements Evaluation
3/7/2023	1.2	Added Section 5 - Nonfunctional Requirements Evaluation
3/8/2023	1.3	Added Section 6 - Unit Testing
4/4/2023	1.4	Updated for final rev

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Symbols, Abbreviations and Acronyms

symbol	description
Age groups	(15-30, 31-50, 51-75, 75+)

1 Purpose

This VnV report's establishment is to support development of the product Synesthesia Wear. Furthermore, the actions taken in the document are linked with testing to ensure reliability and robustness of the product for adequate detection of particular sounds.

2 Scope

The focus of this document is on the output results of Synesthesia Wear when given arbitrary test inputs. Furthermore, black box testing will be used on important aspects of the output and input rather than how the results are being generated. Lastly, these tests will be based on certain implementations we have put into place to handle unexpected inputs.

3 Background

Synesthesia wear is designed with a mobile application which allows customization to occur from their mobile devices and allows users to toggle certain sounds on and off to improve usability of the watch. Synesthesia wear will be able to detect key words and sounds that are customized to the users to aid them with their lack of hearing. As a result, this helps them know when someone is calling their name, during emergencies, and many other situations within their daily lives.

4 Verification Plan

4.1 SRS Verification Plan

- **Review by teammates:** The SRS was reviewed by teammates working in groups of two. This was done in groups so that teammates can discuss between each other to verify and validate our SRS. This also helped to iron out the previous issues and feedback we had received from our peers.

- **Review by stakeholders:** The key functional requirements and some key non-functional requirements were discussed with external stake-

holders. Some non-functional requirements were not discussed as they were not deemed to be important. The external stakeholders that were consulted for our project were Dr. Martin von. Mohrenschildt and Katherine Hesson-Bolton. Both offered valuable information for our project. Dr. Martin von. Mohrenschildt was consulted at the start and the middle of the project while Katherine Hesson-Bolton was consulted throughout the project.

4.2 Design Verification Plan

- **Review by teammates:** The design was reviewed by all the teammates together in a library meeting room. The feedback from our peers and the initial design goals were considered.
- **Review by stakeholders:** The design was also reviewed by our professor and our TAs during revision 0 demonstration. A lot of feedback about our design was received then, which has resulted in a couple of changes in key areas of our project.

5 Functional Requirements Evaluation

Id	Ref	Description	Input	Expected Result	Actual Result	Result
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Id	Ref	Description	Input	Expected Result	Actual Result	Result
FRT1	FR1, FR2	Testing ability to differentiate sounds	Five different sounds	Device produces five different feedbacks	Vibration motor was able to produce different feedbacks when configured with 5 different feedback settings	Pass
FRT2	FR1	Testing in different environments	Same sound in different environments	Same feedback in all enviroments	Feedback was the same in different environments	Pass
FRT3	FR1	Testing at different ranges	Same sound at specified distances	Same feedback at specified distances	Farther distances led to inconsistencies in the feedback	Fail

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Id	Ref	Description	Input	Expected Result	Actual Result	Result
FRT4	FR1	Testing its ability to ignore ambient noise	No input	No output	No vibrations are occuring when background noise is present in the environment	Pass
FRT5	FR2	Testing its ability to classify correctly	Different specified words	Feedback based on correct classification	Feedback is correct with respect to the configured sound classification settings	Pass
FRT6	FR2	Testing variability in speech	Same word said by four different people	Same feedback for all	Some inconsistencies in feedback for people with less training data samples	Fail

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Id	Ref	Description	Input	Expected Result	Actual Result	Result
FRT7	FR2	Testing its ability to ignore high amplitude random sounds	Random not specified sounds	No haptic feedback	No feedback occurred for the random sound samples	Pass
FRT8	FR3	Testing newly set classifications	A newly set classification sound	The specified haptic feedback	The correct feedback for the newly configured sound occurred	Pass
FRT9	FR3	Testing removed classifications	A removed classification sound	No feedback	No feedback took place for the classification sound that was removed	Pass
FRT10	FR3	Testing reboot and memory retention	Power switched on and off and test FRT5 run again	Feedback based on correct classification	Correct feedback still occurred after the device was rebooted	Pass

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Id	Ref	Description	Input	Expected Result	Actual Result	Result
FRT11	FR4	Testing haptic feedback with the device worn	Specified sound	Haptic feedback based on the sound's classification	The appropriate feedback happened even when the device was being worn	Pass
FRT12	FR4	Testing variability in haptic feedbacks	Three different specified sounds	Different haptic feedbacks that convey the specified sounds	Proper feedbacks with respect to each input sound occurred	Pass
FRT13	FR4	Testing different wearable orientations	FRT12 run on different orientations	All orientations give consistent output	The same feedback was present for any device orientation that was used	Pass
FRT14	FR4	Testing intensity of feedback wearing different clothes of varying thickness	FRT12 run on three different clothes	All clothes give consistent results	The thicker clothes lead to inconsistencies in feedback	Fail

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Id	Ref	Description	Input	Expected Result	Actual Result	Result
FRT15	FR5	Testing real-time application of device	Specified sound	Correct classification within one second	Feedback had occurred within one second after an input sound had been said aloud	Pass

Table 1: Functional Requirement Tests

6 Nonfunctional Requirements Evaluation

6.1 Manual

Id	Ref	Description	Input	Expected Result	Actual Result	Result
NFRT3	NFR1	Testing button functionality based on button colour	Open Application	Different coloured buttons perform different functionalities	Buttons with similar colour performed similar functions	Pass
NFRT6	NFR1	Testing usability, accessability, findability of application and device	N/A	Achieve average score of 8 from 10 participants (rated out of 10)		TBD

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Id	Ref	Description	Input	Expected Result	Actual Result	Result
NFRT7	NFR2	Testing user interface's consistency in appearance	N/A	Achieve average score of 4 out of all questions from participants		TBD
NFRT12	NFR4	Testing ability to configure different keywords on application	Click keyword selection button	Keyword configuration screen	Reached keyword configuration screen on application	Pass
NFRT13	NFR4	Testing ability to select language of use on application	Preferred Language	Application translated to preferred language		TBD
NFRT14	NFR4	Testing ability to select language of use on already set-up device	Change Language	Application translated to chosen language		TBD
NFRT15	NFR4	Testing accuracy of translated languages on application	Team translates manuals	Translated manuals		TBD

Table 2: Manual Nonfunctional Requirement Tests

6.2 Stress

Id	Ref	Description	Input	Expected Result	Actual Result	Result
NFRT11	NFR3	Check if you can configure an unrecognizable keyword	Unrecognizable keyword	Keyword not supported	Keyword not supported	Pass
NFRT24	NFR11	Feed 6 samples 50 times each with random noise added. Check if correctly classified 90 percent of the time	Sound clips	90 percent correct classification	82 percent classification. See Figure 2 in Appendix	Fail
NFRT25	NFR12	Check the average battery life of the device by timing when 10 different device runs out of battery	10 fully charged devices	Average battery life of 10 devices is more than 12 hours		TBD
NFRT29	NFR16	Checking the durability of the device including material wear, battery etc	Device	Lifetime of device should be 5 years		TBD

Table 3: Stress Nonfunctional Requirement Tests

6.3 Performance

Id	Ref	Description	Input	Expected Result	Actual Result	Result
NFRT1	NFR1	Checking what the initial state of application is.	Open Application	Home Page of Application	Home Page of Application	Pass
NFRT2	NFR1	Can users find the pairing button of the application.	Open the Application, Click pair button	User clicks pair button under 10 seconds	Users found pairing buttons under 10 seconds	Pass
NFRT4	NFR1	Checking if application correctly goes to pairing page.	Open the Application, Click pair button	Pairing page of Application	Pairing page of Application	Pass
NFRT5	NFR1	Checking if application correctly goes to keyword selection page.	Open the Application, Click keyword selection button.	Keyword Selection page of Application	Keyword Selection page of Application	Pass

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Id	Ref	Description	Input	Expected Result	Actual Result	Result
~~NFRT8~~	NFR3	Check to see if the application connects to the device through bluetooth out of scope	Open application, click pair button on both device and application	Device pairs to Phone	Device Pairs to Phone	Pass
NFRT16	NFR5	Checking if users can pair a device to phone in under 5 minutes	Open application, click pair button on both device and application	3/4 Users fully pair device in under 5 minutes	4/4 Users pair device under 5 minutes	Pass
NFRT19	NFR9	A sound will be fed to the device that includes a keyword device should be able to provide feedback in under 1 second 8/10 times	Sound that includes a keyword	8/10 keywords detected in under 1 second	9/10 Keywords detected. See Figure 1 in Appendix	Pass

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Id	Ref	Description	Input	Expected Result	Actual Result	Result
NFRT20	NFR9	Checking how fast the UI of application responds to user input	User Input	Average of 100 inputs is under 1ms		TBD
NFRT21	NFR9	Checking that application can separately connect to 5 independent devices	Pairing button on both application and device	5/5 devices pair in under 1 minute	All 5 paired in under 1 minute each	Pass
NFRT30	NFR17	Let 10 people use device for 3 days record how many say it inhibits their lives	unpaired device and unopened application	8/10 participants do not the device to inhibit their lives		TBD
NFRT32	NFR17	Check to see if users can install the application on IOS and Android	Click Install	installed application on IOS and Android	Installed on Android	Fail

Table 4: Performance Nonfunctional Requirement Tests

6.4 Security

Id	Ref	Description	Input	Expected Result	Actual Result	Result
NFRT9	NFR3	Checking if application pairs to device that is not in pairing mode	Click pair Button	Device not found	Device not found	Pass
NFRT10	NFR3	Check if user can Login to application without a registered account	Invalid Login Credintials	Account not found	Account not found	Pass

Table 5: Security Nonfunctional Requirement Tests

6.5 Recovery

Id	Ref	Description	Input	Expected Result	Actual Result	Result
NFRT18	NFR8	Check to see if a initially paired device will automatically repair when taken out of range than put back into range	Take device in/out of range	device should rapair 90 percent of the time	device repaired 100 percent of the time	Pass

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Id	Ref	Description	Input	Expected Result	Actual Result	Result
NFRT22	NFR9	Checking to see how long it takes a paired device to repair when brough back into range.	place device back into range	Average time of re-connection should be 10 seconds or less	Average time was 6 seconds	Pass

Table 6: Recovery Nonfunctional Requirement Tests

6.6 Visual

Id	Ref	Description	Input	Expected Result	Actual Result	Result
NFRT17	NFR6	people from different age groups will be shown icons found in application and asked if they can identify their meaning	N/A	All 5 icons named by 3/4 participants of each age group		TBD
NFRT23	NFR10	Check if battery is visual on the final device	N/A	Battery should not be visible	Battery is not visible	Pass

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Id	Ref	Description	Input	Expected Result	Actual Result	Result
NFRT31	NFR17	Check if the device is adjustable such that it fits on different sized wrists	Adjust size	Should fit wrists of size 6-8.5 inches	Fits specified Wrist sizes	Pass
NFRT34	NFR25	Check if the code has anything that would be offensive to any groups	N/A	There should not be anything offensive present	Nothing that is offensive was found	Pass

Table 7: Visual Nonfunctional Requirement Tests

6.7 Load

Id	Ref	Description	Input	Expected Result	Actual Result	Result
NFRT26	NFR12	Device will be turned on for a duration of 5 hours during which keywords will be fed at randon time intervals. Test passes if device reacts at each interval	Sound clips	Device should react at each of teh 5 random intervals	device reacts at 5/5 intervals	Pass

Table 8: Load Nonfunctional Requirement Tests

6.8 Regulation

Id	Ref	Description	Input	Expected Result	Actual Result	Result
NFRT35	NFR26	Team of lawyers will check if the project as a whole corresponds with all legal rulations and requirements.	N/A	Project follows all legal requirements		TBD

Table 9: Regulation Nonfunctional Requirement Tests

6.9 Upgrade

Id	Ref	Description	Input	Expected Result	Actual Result	Result
NFRT27	NFR12	Helper code will be used to check if application is currently up if application goes down the developers will recieve an email	N/A	Application should have a continous uptime of 1 year		TBD

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Id	Ref	Description	Input	Expected Result	Actual Result	Result
NFRT28	NFR15	Check if products supports up to 10 keywords 2 years after launch.	10 keywords	product will support at minimum 10 keywords		TBD
NFRT33	NFR20	Try and using the device 24 hours after a major update has been pushed to the application	Input a sound	Device should retain 100 percent functionality		TBD

Table 10: Upgrade Nonfunctional Requirement Tests

7 Safety Requirements Testing

Id	Ref	Description	Input	Expected Result	Actual Result	Result
SRT1	SIR1	The powered device will be checked for live current at all possible contact locations with the user's hand.	Multimeter probe	No live current	No live current detected	Pass

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Id	Ref	Description	Input	Expected Result	Actual Result	Result
SRT2	SIR2	The device auto-shutoff feature will be checked, to protect against abnormal current characteristics.	VCC connected to 10 volts	The controller detects it and isolates itself	The controller was able to protect itself	Pass
SRT3	SR3	Check if the powered device stays within the allocated temperatures.	Thermocouple probe	Temperature difference is less than 5 degrees	Temperature difference was 3 degrees	Pass
SRT4	SR4	Check if the data and functionality of the device are retained if the power is cutoff abruptly.	Power disconnected and connected	The device restarts correctly with any loss of functionality	The device restarted correctly	Pass
SRT5	ACR1	Check if the user can update the intensity of the vibration device. Out of scope	N/A	N/A	N/A	TBD

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Id	Ref	Description	Input	Expected Result	Actual Result	Result
SRT6	ACR2	Check if the application can handle invalid inputs and not break.	Invalid inputs	No reaction	No reaction	TBD
SRT7	ACR3	Check if the application is able to alert the user if an incompatible device has been used. Out of scope	N/A	N/A	N/A	TBD
SRT8	IR3	Check if the device syncs automatically when it is connected to the application.	New connection	Settings updated	Settings updated	TBD
SRT9	IR4	Check if the application prevents the user from selecting the same vibration for two different classes.	Same vibration setting for two different classes	Error message	Did not allow the change	Pass

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Id	Ref	Description	Input	Expected Result	Actual Result	Result
SRT10	IR5	Check if the application tries to sync only when it needs to.	Random application movement	No sync request until a change in settings	Correct output	Pass
SRT11	IR6	Check if the device can handle a sound of 90dB without breaking.	90 dB keyword sound	Correctly classified and retains functionality	Correct classification	Pass
SRT12	IR7	Check if the application can handle incorrect Bluetooth signals.	Corrupted Bluetooth transmission received	Error message	Does not make any change	Pass
SRT13	IR8	Check if the device will alert the user if the phone has been randomly disconnected.	Abrupt disconnection	Haptic and visual feedback to the user	No output	Fail

Table 11: Safety Requirement Tests

8 Unit Testing

The following test cases were derived from the unit test section shown in Synesthesia Wear's *VnVPlan.pdf Document* as well as the modules shown in the *MIS.pdf Document*. Furthermore, inapplicable tests from the VnVPlan were not included in the following table as they were not feasible with our current implementation. To make the unit tests applicable we will make im-

provements to the sound classification module and bluetooth communication

Id	Ref	Description	Input	Expected Result	Actual Result	Result
UT1	M4, M9	Testing accuracy of the microphone to detect sounds	3 Different Sample Recordings	3 Distinct Sample Recordings in memory buffer that match the inputs respectively	The detected sounds matched the input sounds	Pass
UT3	M8	Testing bluetooth's ability to send signals accurately	Sample classification signal asserted on software	Feedback signal asserted on hardware	According to the classification signal, the correct feedback signal was sent to the vibration motor	Pass

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Id	Ref	Description	Input	Expected Result	Actual Result	Result
UT4	M7	Testing classification module's ability to accurately categorize sound data	Stored samples of sound data in the memory buffer	Accurately classified Sound Data	The classification of the input sound samples were accurately categorized with a confidence level of 80% or more	Pass
UT5	M7	Testing classification module's ability to change its sound classification settings	New Classification settings	Classification settings have been changed on the app	The settings displayed on the settings page match the newly inputted classification settings	Pass

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Id	Ref	Description	Input	Expected Result	Actual Result	Result
UT6	M4, M7	Testing feedback module's ability to transmit accurate feedback signals according to the settings	Feedback signal is asserted	Vibration detected in the bracelet that coincides with the feedback signal	Vibration motor went off appropriately with respect to the settings configured on the app	Pass
UT9	M2, M8	Testing bluetooth connection ability	Enable bluetooth connection	Bluetooth connection connected in under a minute	Bluetooth connection was established within 10 seconds	Pass

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Id	Ref	Description	Input	Expected Result	Actual Result	Result
UT10	M2, M9	Testing bluetooth connection's ability when devices go in and out of range	Separate the connected devices 10 or more metres away, wait at least 5 seconds, then bring the devices closer together	Bluetooth will disconnect and reconnect when devices are back in range to each other	Bluetooth was unable to automatically reconnect when devices went back in range	Fail
UT11	M4	Testing noise filtering module's ability to remove noise from a sample sound	Digital data with one or more sounds	Same digital sound recording but with less noise	The output still had noise but notably less compared to the original sound file	Pass

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Id	Ref	Description	Input	Expected Result	Actual Result	Result
UT15	M5	Testing app interface's ability to respond quickly to a user input	User input	User Interface response within 1ms	The app was appropriately able to respond as soon as a button was clicked or an input was submitted	Pass
UT16	M5	Testing app interface's ability to respond the same across different systems (Android, Windows, IOS)	User Input	Same User Interface response on all the different devices	N/A (The app has not yet been implemented on different IOS systems)	N/A

Table 12: Unit Tests

9 Changes Due to Testing

Test results marked as Fail require revisions in future implementations.

9.1 Changes Due to Requirement Tests

- Add capability to detect sounds at greater distance (>15m)
- Update sound detection model performance by being more generalizable (i.e. detect sound from different individuals)

- Increase accuracy by adding sound clips with various environmental sounds.
- Change the confidence level of sound detection
- Intensity of haptic feedback

9.2 Changes Due to Unit Tests

- Add further bluetooth capability to reconnect device with mobile application after device goes in and out of range
- Increase sensitivity of microphone
- Allow for auto bluetooth connection

10 Traceability Matrices

All of our tests can be traced back to either functional requirements, non-functional requirements and modules.

Test	**Requirements**				
	FR1	**FR2**	**FR3**	**FR4**	**FR5**
FRT1	X	X			
FRT2	X				
FRT3	X				
FRT4	X				
FRT5		X			
FRT6		X			
FRT7		X			
FRT8			X		
FRT9			X		
FRT10			X		
FRT11				X	
FRT12				X	
FRT13				X	
FRT14				X	
FRT15					X

Table 13: Traceability between functional requirement tests and functional requirements

Given our size of non-functional requirements, we have grouped some of the tests into test types for ease of understanding.

Test Cases	**Requirements**
Manual Non-functional	NFR1
	NFR2
	NFR4
Stress Non-functional	NFR3
	NFR11
	NFR12
	NFR16
Performance Non-Functional	NFR1
	NFR3
	NFR5
	NFR9
	NFR9
	NFR17
Security Non-Functional	NFR3

Table 14: Traceability between test cases and non-functional requirements

Modules	Unit Tests									
	T1	**T3**	**T4**	**T5**	**T6**	**T9**	**T10**	**T11**	**T15**	**T16**
Login Module M1										
Bluetooth connection Module M2						X	X			
Keyword Selection Module M3										
Output Signal Module M4	X				X			X		
Profile Module M5									X	X
Battery Status Module M6										
Sound Classification Module M7			X	X						
Bluetooth Communication Module M8		X			X	X				
Microphone Module M9	X						X			

Table 15: Traceability between modules and unit tests.

11 Appendix

11.1 Test Results

Response Time

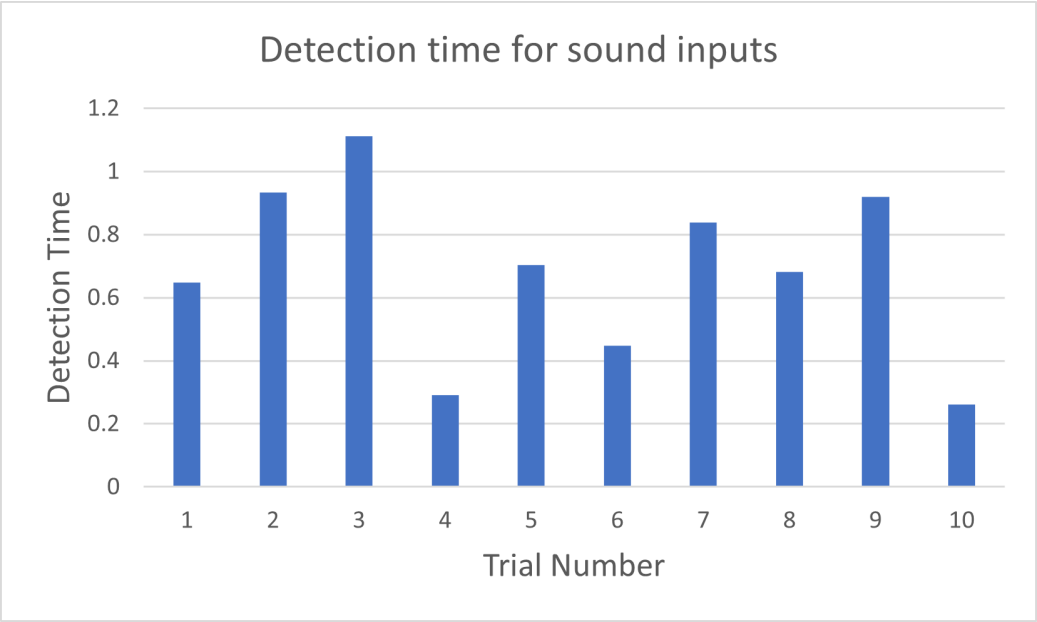

Figure 1: Detection time for sound inputs

Model Accuracy Histogram

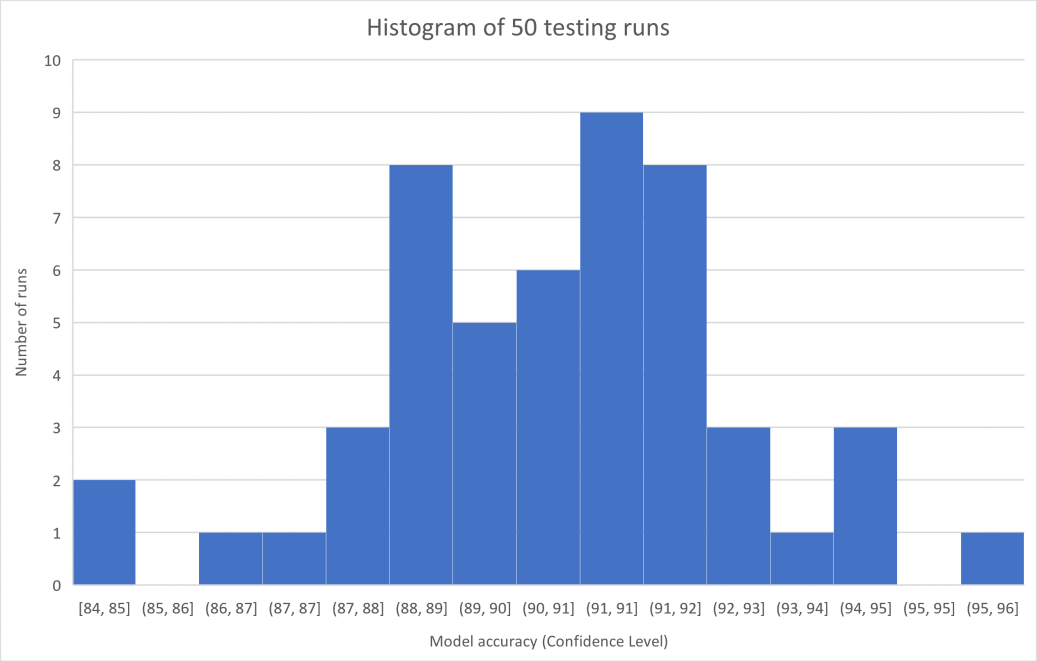

Figure 2: Histogram of 50 testing runs

11.2 Reflection

After reviewing both the VnV Plan and the VnV Report, it is clear that there are numerous differences between the predicted outputs shown within the VnV plan and the experimental results found in the VnV report. For example, functional requirement test 3 (FRT3) had a 'fail' result in the VnV report compared to the VnV plan which had predicted the same haptic feedback at different distances. With this in mind, these kinds of differences indicate that some of the results were not part of the initial expectations and that the Synesthesia Wear team needs to work on finding ways to remove these inconsistencies to further improve and solidify the product.

In another regard, some of the differences were found to be based on surveys which will be conducted after the final revision is completed. An example is nonfunctional requirement test 17 (NFRT17) where a survey will

be taken for people in different age groups for icons found in the application. The icons are an aesthetic aspect to the app that have not been implemented yet, but by the time this test is run, they will be included before the survey is performed.

With all this in mind, to improve upon the differences between the two documents, the team will collaboratively brainstorm ideas for fixes/solutions to inconsistent results and possibly try to come up with even more test cases such that it prevents undesirable results from occurring in the first place. For example, testing that invalid sounds are being blocked so that it prevents undesirable haptic feedback from occurring to begin with. Questions that would arise from this train of thought would be concerns like 'what would be considered an invalid keyword?'. Furthermore, thinking about the consequences for the test failures and what the back up plan would have to be in those situations. Lastly, trying to look for alternative options to get the desired output would also be something that needs to be considered.

11.3 Synthesis

To conduct our tests, data was required to be collected. Our functional requirement, nonfunctional requirement, and unit tests were carried out to determine the quality and effectiveness of our project. A majority of our tests passed, some were not able to be tested at this point in the development of our project. Additionally, a few tests failed. These are areas in which we will focus our next revision to improve. For example, we could make our sound classification model more robust, since the data we collected (experiments we ran) did not pass expected results. Overall, our goal is to have all of our test results as passes.