

ANALYSIS OF AUDIO RECORDINGS MADE USING THE VOICE RECORDER APPLICATION ON
ANDROID PHONES

by

GINA ANTOINETTE DEANGELIS

A.A., Arapahoe Community College, 1999

B.S., University of Colorado Denver, 2001

A thesis submitted to the
Faculty of the Graduate School of the
University of Colorado in partial fulfillment
of the requirements for the degree of
Master of Science
Recording Arts Program
2020

© 2020

GINA ANTOINETTE DEANGELIS

ALL RIGHTS RESERVED

This thesis for the Master of Science degree by

Gina Antoinette DeAngelis

has been approved for the

Recording Arts Program

by

Catalin Grigoras, Chair

Jeff M. Smith

Marcus Rogers

Date: May 16, 2020

DeAngelis, Gina Antoinette (M.S., Recording Arts)

Analysis of Audio Recordings Made Using the Voice Recorder Application on Android
Phones

Thesis directed by Associate Professor Catalin Grigoras

ABSTRACT

Android is one of the two main operating systems for mobile phones and includes an application for voice recording. Since extensive research has been completed on the "Voice Memos" application for iOS, there remains research to be completed on the default application for the Android OS. This thesis explores the user interface for four different Android phones with four different voice recording application versions. Features, limitations, editing capabilities, file formats and atom structure for each phone are discussed. A testing protocol was created and utilized for the creation of the test recordings. The analysis of those recordings explored authenticity, detected editing and discovered consistencies and inconsistencies between the recordings for each phone.

The form and content of this abstract are approved. I recommend its publication.

Approved: Catalin Grigoras

DEDICATION

This is dedicated to my parents and my boys who supported me every step of the way.

Your sacrifices did not go unnoticed.

ACKNOWLEDGEMENTS

First, I would like to thank Rich Sanders who first introduced me to audio forensics. His passion for audio and his brilliance were inspiring and I wish I hadn't waited 16 years to finally see this through. You are truly missed!

Secondly, to my mom who helped proofread and edit all my papers from elementary school all the way through this thesis. Your dedication and support have been incalculable. I could not have done this without you!

To Andrew Hill whose thesis, "Analysis of Audio Recordings made using "Voice Memo's" Application for iOS", was the backbone for this thesis; thank you for all your hard work. To Douglas Lacey, Jeff Smith, Catalin Grigoras and Bruce Koenig whose conference paper on "Triage Approach for the Forensic Analysis of Apple iOS Audio Files Recorded Using the "Voice Memos" App", was also key in the development of this paper. Thank you for your dedication to the field.

Lastly, I would like to thank everyone at the NCMF – your support was instrumental. To my 17-19 cohort, thank you for all your support, encouragement and "late night seminars". I feel very honored and privileged to be a part of such a great group! A special shout out to Doug – thank you for the hours spent with me over the phone, over the computer and via email "holding my hand". You mentored me and helped me laugh through the most stressful times of the program. I hope to repay the favor someday.

To my Heavenly Father who made everything possible, thank you!

TABLE OF CONTENTS

CHAPTER

I. INTRODUCTION	1
Android Devices.....	3
Previous Research	3
II. VOICE RECORDER USER INTERFACE.....	5
Device #1: HTC One, Android 5.0.2 Lollipop, Voice Recorder 6.3.843363.....	5
Editing.....	10
Device #2: LG Q6, Android 7.1.1 Nougat, Audio Recorder 6.1.8.....	10
Features and File Formats	10
Editing.....	14
Device #3: Samsung Galaxy S6, Android 7.0 Nougat, Voice Recorder 20.1.86.12	17
Device #4: Samsung Galaxy S9, Android 10, Voice Recorder 21.2.00.42.....	17
Features and File Formats	18
Editing.....	21
Interrupted Recordings with Phone Calls.....	23
III. TEST RECORDING PROTOCOL	24
LG Q6.....	24
Samsung S6 and S9.....	25
IV. RESULTS.....	26
Device #1: HTC One	27
Device #2: LG Q6	30
Consistencies and Inconsistencies.....	30

Atom Structure	31
Device #3: Samsung S6	31
Consistencies and Inconsistencies.....	31
Atom Structure	32
Device #4: Samsung S9	34
Consistencies and Inconsistencies.....	34
Atom Structure	34
V. CONCLUSION	36
Future Research.....	36
REFERENCES	38
APPENDIX	
A. TEST RECORDING COLLECTION PROTOCOL FOR LG Q6	39
B. TEST RECORDING COLLECTION PROTOCOL FOR SAMSUNG S6 AND S9	43

LIST OF TABLES

TABLE

1: Mobile Phone Overview.....	2
2: Digital Audio Specifications	5
3: Comparison of Unedited and Edited Recordings on the Q6	31
4: Comparison of Unedited and Edited Recordings on the S6.....	33
5: Comparison of Unedited and Edited Recordings on the S9.....	35

LIST OF FIGURES

FIGURE

1: Voice Recorder App Icon.....	5
2: Voice Recorder User Interface	6
3: Voice Recorder While Recording.....	7
4: Renaming Options	7
5: Recording Options	8
6: File Format Options.....	9
7: Audio Recorder App Icon.....	10
8: Audio Recorder User Interface	11
9: Audio Recorder While Recording	12
10: Recording Default Name.....	12
11: Recording Options.....	13
12: Details of the Recording.....	14
13: Finished Recording.....	15
14: Editing the Beginning and Ending of the Recording.....	16
15: Editing the Middle of the Recording	16
16: Voice Recorder App Icon	17
17: Voice Recorder User Interface.....	19
18: Voice Recorder While Recording	19
19: Recording Options.....	20
20: File Format Options.....	20
21: Editing Markers.....	21

22: Editing Options.....	22
23: QuickTime File Format Movie Atom Example	26
24: Edited Audio in Voice Recorder	28
25: AMR-NB Hex Data	28
26: AMR-WB Hex Data	28
27: AAC Hex Data	29
28: Header Information in Hex Editor	30
29: Footer Information	30
30: Hex Data Header of Unedited Recording.....	32
31: Hex Data Header of Edited Recording.....	33

CHAPTER I

INTRODUCTION

Android smartphones, developed by Google, were first released in September 2008 with the T-Mobile G1 (in the US) or HTC Dream (in the UK and Europe). From version 1.0 to Android 11 (due to be released during the third quarter of 2020) the operating system (OS) has undergone major changes over the years. One of the unique traits of the Android OS is that each version (up to 10) was associated with a dessert, i.e., Android 5.0 Lollipop, 6.0 Marshmallow, 7.0 Nougat, and 9.0 Pie. Android 10.0 introduced a new look to the Android brand, including a new logo and abandoning the dessert name [1].

By 2018 “of the 1.56 billion smartphones sold worldwide in 2018, around 1.35 billion were running the Android operating system” [2]. One of the main reasons for this is that Android is an open-source platform, allowing mobile phone manufacturers to adapt the OS for their own devices, which includes Samsung, Nokia, Motorola, HTC, LG, Google Pixel and others.

The development and popularity of all mobile phones, Android and iOS (iPhone Operating System), means that they are easily accessible and readily available for just about any need. The size of and the growing dependence of society on mobile phones makes them available and utilized everywhere. Between the millions of apps available for download on the Android phone and the built-in capabilities, including the built-in camera, GPS, calling, texting, and video/audio recorders, the uses are endless.

“Mobile forensics, arguably the fastest growing and evolving digital forensic discipline, offers significant opportunities as well as many challenges” [3]. Their ability to track locations, phone calls, texts and other types of communication can make them key

components to an investigation. The abilities to properly identify, examine, and verify information from a mobile phone are very important aspects of forensic research. Different applications and their abilities are also important to research and understand, not just for the scientific community, but also for individuals who use these devices every day.

This paper explores the capabilities of the voice recording application that comes standard on the Android phone. Four different Android phones with four different versions of the app were tested for recording and editing capabilities and different characteristics for each device were investigated. This is merely a preliminary study to determine the feasibility of these applications. It is important to verify authentication and provenance, as well as consistencies and inconsistencies between the devices.

Table 1: Mobile Phone Overview

PHONE	ANDROID VERSION	VOICE RECORDER VERSION
HTC ONE	5.0.2	6.3.843363
SAMSUNG GALAXY S6	7.0	20.1.86.12
LG Q6	7.1.1	6.1.8
SAMSUNG GALAXY S9	10.0	21.2.00.42

All devices tested allow the ability to share the recordings via messages, email, Android Beam, Bluetooth, and Gmail. The Samsung phones also allow sharing via Outlook, OneNote, Samsung Cloud Drive and many others depending on what other communication apps are installed on the phone. All devices, except for the LG Q6, allow the files to be renamed, deleted, shared and a few other options. All devices, except for the HTC One, allow for some type of editing, which will be discussed in further detail later.

Testing protocols were established for the LG and Samsung phones since their voice recording apps offer the most features (see Appendix A and Appendix B).

Android Devices

In order to conduct a preliminary survey of Android Voice Recorder apps, the following Android devices were investigated for this study:

- HTC One Sense, PN072, released in March 2015, Android version 5.0.2 Lollipop
- Samsung Galaxy S6, SM-G920P, released in April 2015, Android version 7.0 Nougat
- LG Q6, GL-US700, released in March 2017, Android version 7.1.1 Nougat
- Samsung Galaxy S9, SM-G960U, released January 2018, Android version 9.0 Pie (updated to 10.0 during this study)

Since there are hundreds of different Android phones it would be impossible to conduct a survey of all these phones for the scope of this paper; however, the phones listed above supplied adequate information as a starting point for further research on other models.

The LG Q6, as mentioned above, does have the ability to add Location and Event Tags to the recording, but since there was no cell service provided for this phone during the time of testing, those options were not available. Only the Samsung S9 had service, and so it was the only one utilized to test interruptions on the app with incoming calls.

Previous Research

At the AES International Audio Forensics Conference in 2017, Jeff Smith, Catalin Grigoras, Douglas Lacey and Bruce Koenig presented a paper entitled “Triage Approach for the Forensic Analysis of Apple iOS Audio Files Recorded Using the ‘Voice Memos’ App” [4]. This paper described the testing of recordings captured, edited and interrupted on iPhones to determine the functionality of the app. Based upon the data collected, a decision tree was then created to assist with the examinations of file originality.

Andrew Hill, in his thesis, “Analysis of Audio Recordings Made Using ‘Voice Memos’ Application for iOS” [5], expanded upon the research conducted by Smith, Grigoras, Lacey and Koenig. Both Hill’s thesis and the conference paper were limited to the iOS.

This thesis takes the general concepts from the conference paper and Hill’s thesis and applies them to the Android OS. There were many features that were different between the “Voice Memos” app on the iOS and the “Voice Recorder” app on the Android OS. The goal was not to compare the two OS’s but to explore the “Voice Recorder” app on the Android as had the previous work on the iOS. The features and functions, as well as the limitations of the “Voice Recorder” app, will be discussed in the next chapter.

CHAPTER II

VOICE RECORDER USER INTERFACE

All phones investigated had unique audio encoding and container properties. Audio encoding algorithms determine how the file will be encoded (written) and decoded (played back). The container (wrapper) specifies how the media data and metadata is organized [5]. The table below gives an overview of all phones and their file formats. It also includes their bit rate and sample rate. Each one is discussed in detail with each phone that was tested.

Table 2: Digital Audio Specifications

PHONE	ENCODING	CONTAINER	BIT RATE (kbps)	SAMPLE RATE (kHz)
HTC One	AMR-NB	AMR	12.8	8
	AMR-WB	AMR	12.8	16
	AAC-LC	MPEG-4	128	44.1
LG Q6	AAC-LC	m4a	96	44.1
S6	AAC-LC	m4a	64	44.1
			128	44.1
			256	48
S9	AAC-LC	m4a	64	44.1
			128	44.1
			256	48

Device #1: HTC One, Android 5.0.2 Lollipop, Voice Recorder 6.3.843363



Figure 1: Voice Recorder App Icon

Features and File Formats

This version of the Voice Recorder app has several different options and settings for the audio recordings. It contains the basic controls of “record”, “pause”, “stop”, and “play”. Once a recording is made, the user is prompted to keep the default name or to rename it (**Figure 4**). There is also an option to rename the file later if needed. The audio file can be shared through several communication applications including but not limited to: messages, drive, email, Gmail and others depending on what is installed on the phone. The files can also be deleted and removed from the app. (It is unknown whether the phone retains the audio recording or not, that was outside the scope of this paper.) The app also allows the user to set the audio recording as a ringtone (see **Figure 5**).

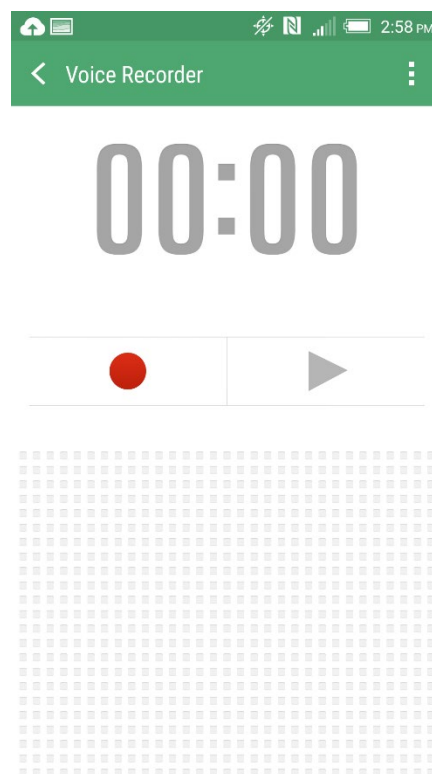


Figure 2: Voice Recorder User Interface

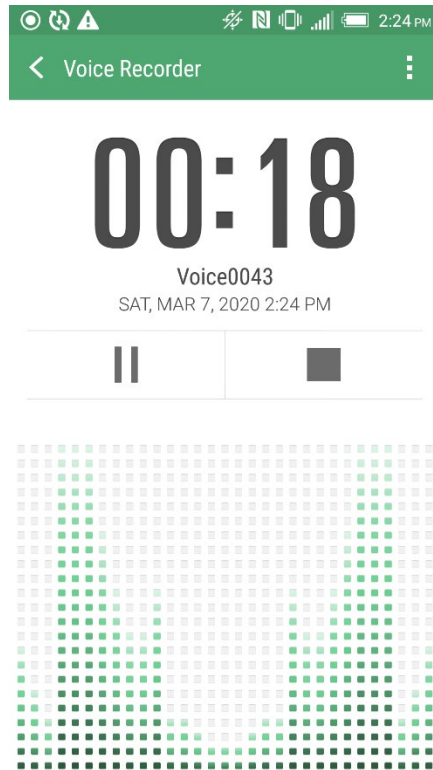


Figure 3: Voice Recorder While Recording

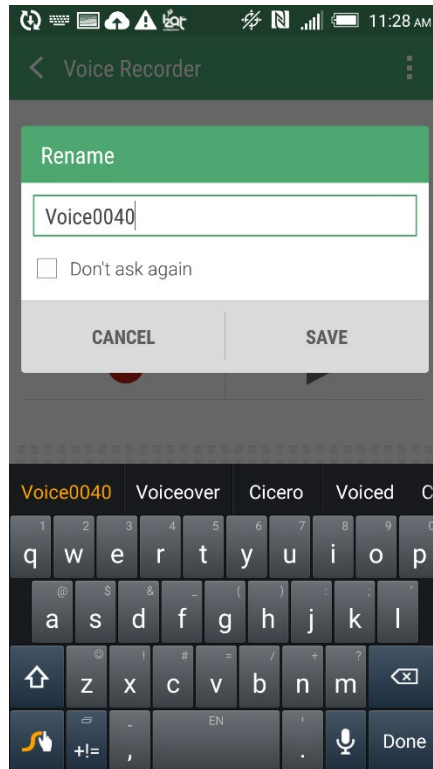


Figure 4: Renaming Options

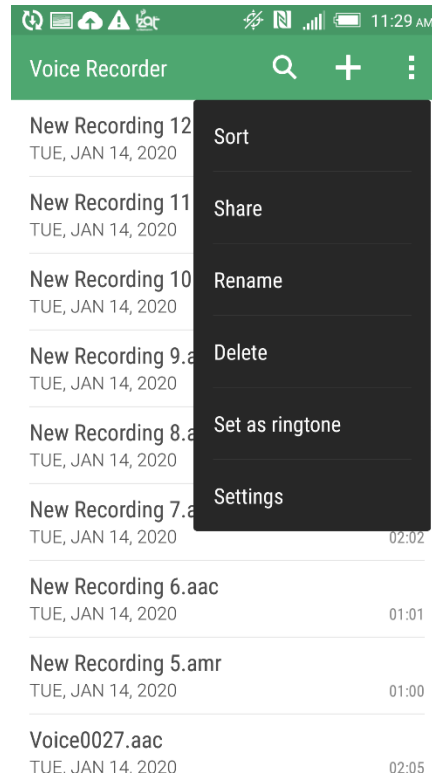


Figure 5: Recording Options

The Voice Recorder app on the HTC One records only in mono from the built-in microphone, but allows for three different file formats: normal quality which is Adaptive Multi-Rate Narrowband (AMR-NB), better quality which is Adaptive Multi-Rate Wideband (AMR-WB) (this is the device's default setting) and high quality which is Advanced Audio Coding Low Complexity (AAC-LC) (**Figure 6**). All of the above formats are lossy compression formats, which means the quality of the recording is diminished and data is lost (that cannot be retrieved in its original form) in order to save on the file size. This allows for less storage space to be used on the phone. Lossless compression is another type of compression that contains more information on the audio file, giving the ability to reconstruct the full quality of the audio without any loss [6]. The drawback for lossless compression is the file size. Lossless compression file sizes are not practical for mobile

phones. Since the HTC One does not have any external memory options, file size can become a factor if the user is planning on storing a large amount of information on this device.

AMR-NB and AMR-WB are common audio compression formats in mobile phones. ACC-LC is another very common file format that compresses the file size. While these file formats will not sound any different to the average listener, in a good quality listening environment they can lose depth and richness since the quality of the audio has been affected to save on file space.

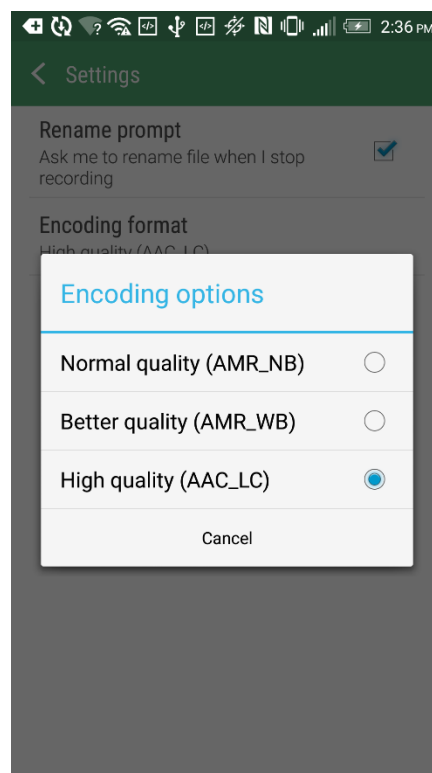


Figure 6: File Format Options

Editing

The Voice Recorder does not have any editing capabilities. There are no options to trim or delete any section of the recording. The user also cannot record over a previous recording in part or in whole. However, a voice recording can be downloaded to the computer, edited in a third-party editing software, and then downloaded again to the app as long as the edited file is saved as any of the available file formats.

Device #2: LG Q6, Android 7.1.1 Nougat, Audio Recorder 6.1.8

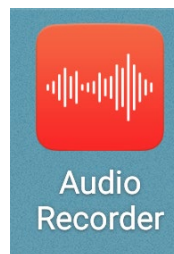


Figure 7: Audio Recorder App Icon

Features and File Formats

LG labeled their recording app the Audio Recorder, but it has similar features and functions as the other Androids that were tested. It, too, retains the ability to “record”, “pause”, “stop” and “play”, as well as a bookmark tool that can be used during or after a recording. Before a recording is made, there is an option to add Event or Location tags. This permits the recording to be attached to an event on the user’s calendar or the location information will be included in the details of the file. Since this phone did not have service at the time of testing, these features were not tested.

The recordings are automatically saved when the recording is stopped and are saved under a default name that can later be renamed. The recordings can be shared via Android Beam, Bluetooth, or through various communication apps like Gmail, messages,

and can also be saved in the app QuickMemo+ (which comes standard on the phone). Like the HTC One, recordings can be deleted, and they will no longer be available in the app.

The Q6 phone can only record in mono and has one file format: AAC-LC at 96 kilobytes per second (kbps) 44.1kHz sample rate. This phone does offer the capacity for external storage and the app grants the user a choice of internal or external memory before starting the recording; however, once the recording is made, it cannot be moved to the other storage unit.

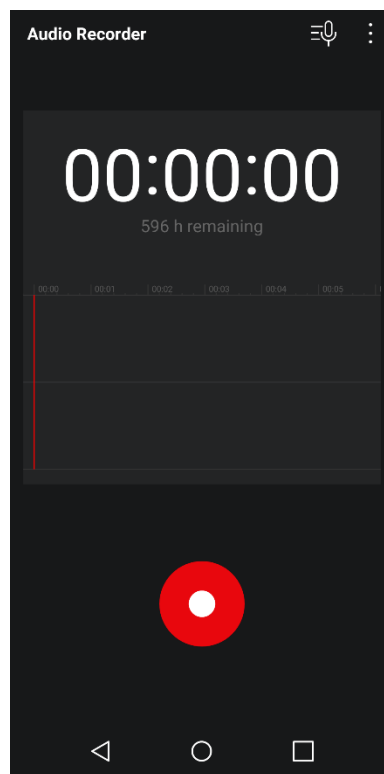


Figure 8: Audio Recorder User Interface

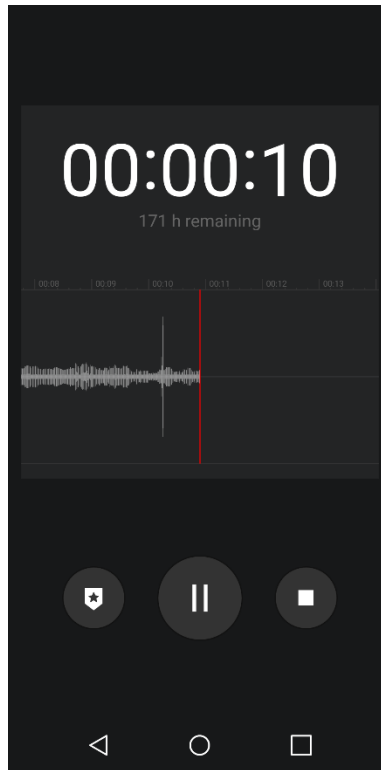


Figure 9: Audio Recorder While Recording

It is interesting to note that the default save name includes the date of the recording as the beginning numbers but ends with “Normal” (**Figure 10**). This would leave the user to believe that there are other recording settings besides the default setting, but after further investigation there are no other quality settings.

20191010_142030_Normal

Figure 10: Recording Default Name

By pressing and holding a specific recording, a new window pops up allowing the user to delete the recording, set it as a ringtone, or view the details of the recording (**Figure 11**).

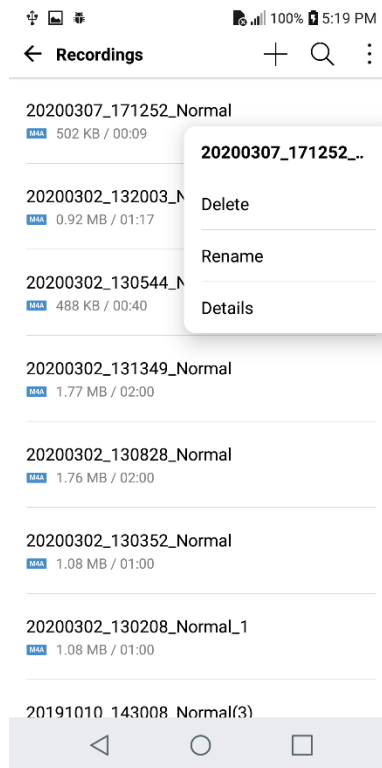


Figure 11: Recording Options

The details page (**Figure 12**) shows the user the title of the recording, the size of the file, the date and time of the recording, the type of file, the duration, and the path where the file is saved.

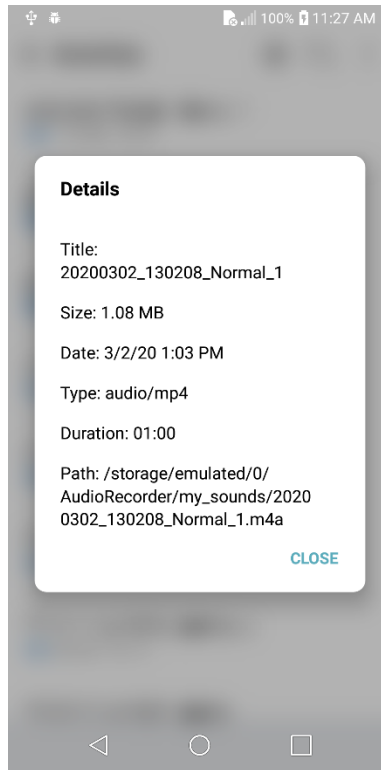


Figure 12: Details of the Recording

Editing

The LG Q6 does have editing capabilities. Once the recording has been completed and saved the user can select the scissors icon (**Figure 13**) to edit the selected recording. The user can share the file or delete the file here as well.

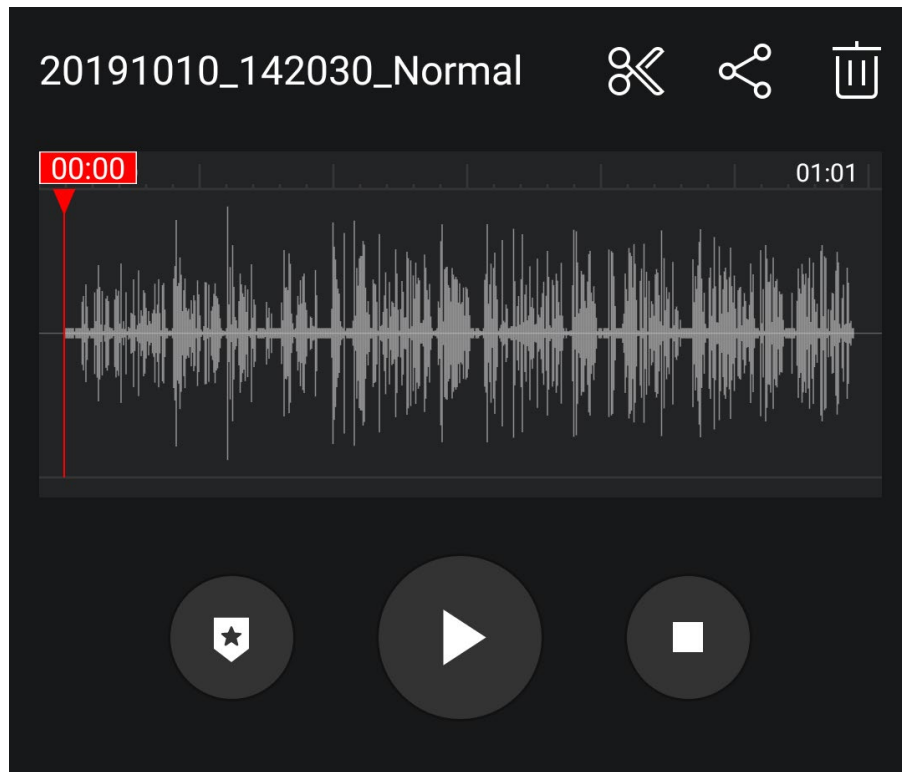


Figure 13: Finished Recording

Once the scissors icon is selected, the start and edit points can be moved to the desired location. For this particular app the beginning and ending of the recording can be trimmed. Simply select the location for the edit (the highlighted area). Once the settings are correct, the user can select the check icon and the highlighted area will be saved; so, the area left outside the recording will be saved. (If the x icon is selected, the editing window will exit, and the list of recordings will now be visible). In **Figure 14** below, the beginning of the file and the end of the file are saved.

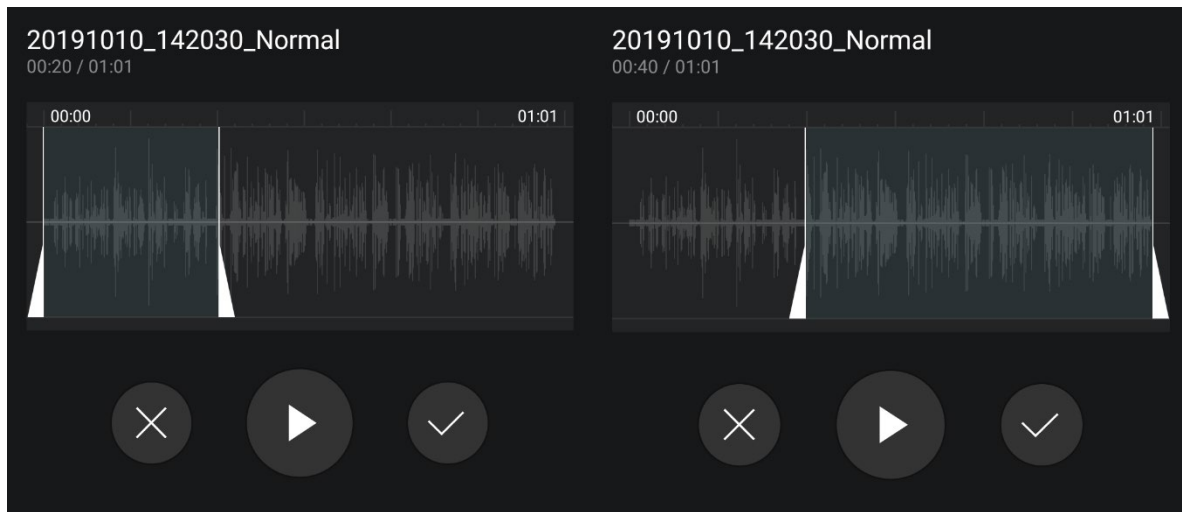


Figure 14: Editing the Beginning and Ending of the Recording

When it comes to the middle section of the recording, it is possible to select the middle section (**Figure 15**) and save what has been selected deleting before and after that area. It is not possible to delete the middle section of the recording and have the beginning and ending spliced together.

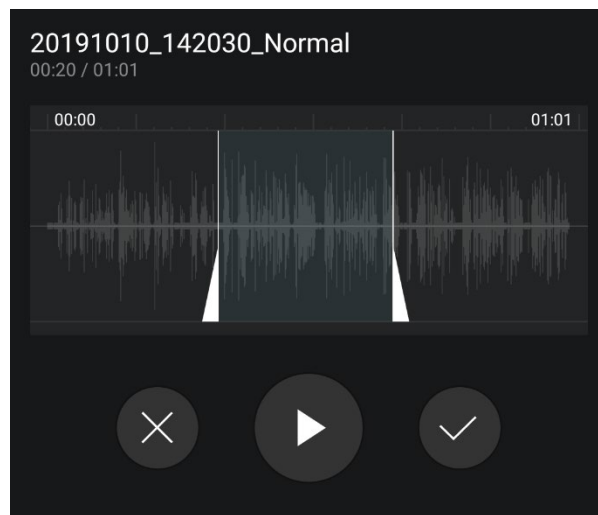


Figure 15: Editing the Middle of the Recording

It is not possible to delete (cut) a section of the recording and add (paste) it somewhere else in the recording or add it to another recording. It is also not possible to record over a previous recording, in part or in the whole; however, when editing has been done to the recording, the option for saving is to create a new file or overwrite the original. If creating a new file is selected, the user can keep the default name or rename the file then.

Device #3: Samsung Galaxy S6, Android 7.0 Nougat, Voice Recorder 20.1.86.12

Device #4: Samsung Galaxy S9, Android 10, Voice Recorder 21.2.00.42

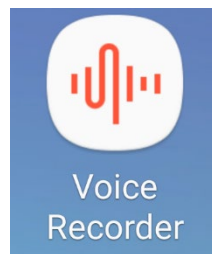


Figure 16: Voice Recorder App Icon

Even though both phones were different Android versions and the Voice Recorder app was different versions the interface was identical in look and ability. So, these two phones were grouped together for the testing protocol. This Voice Recorder app is the most user friendly and has the most editing capabilities.

Before the testing on Android 9 could be completed, the phone updated overnight from Android 9 to 10 and the Voice Recorder app was also updated from version 21.1.06.11 to 21.2.00.42. The recordings that were completed before the update have been included in this paper, but they are not as extensive as the recordings completed for Android 7 and 10. The S9 did have service during the testing and so interruptions from incoming calls were also tested. The S6 does not have the capability for external storage; however, the S9 does.

Features and File Formats

The Voice Recorder app includes the basic audio controllers, “record”, “pause”, “stop” and “play”. This version offers a Standard Mode, an Interview Mode and a Speech-to-text Mode (**Figure 17**). The Standard Mode was used for the testing protocol. The Interview Mode records from both mics on the top and bottom of the phone (which did not reveal anything different from Standard Mode with a stereo setting when examined), and the Speech-to-text Mode was not tested since it is outside the scope of this paper. Bookmarks and blocking calls while recording are other features that this version includes. It also features different playback options: skip muted sections, repeat the recording, and change the speed of the playback from x0.5 to x2.0, the normal speed is x1.0.

The S6 and S9 allow the user to share the recordings through communication apps such as Messages, Mail, Gmail, Messenger (FB) and Outlook, and via Android Beam, Samsung Cloud Drive, Bluetooth, Samsung Notes, and Samsung Drive. These phones also offer the capabilities to edit, rename, delete, convert speech-to-text, move to a secure folder and display the details of the recording (**Figure 19**).

The Voice Recorder for the S6 and the S9 grants three different file formats, all of which can be recorded in mono or stereo: Low quality (64kbps, 44.1kHz), Mid quality (128kbps, 44.1kHz), and high quality (256kbps, 48kHz) (**Figure 20**). All recordings are saved as an m4a, which is another common container file format.



Figure 17: Voice Recorder User Interface



Figure 18: Voice Recorder While Recording

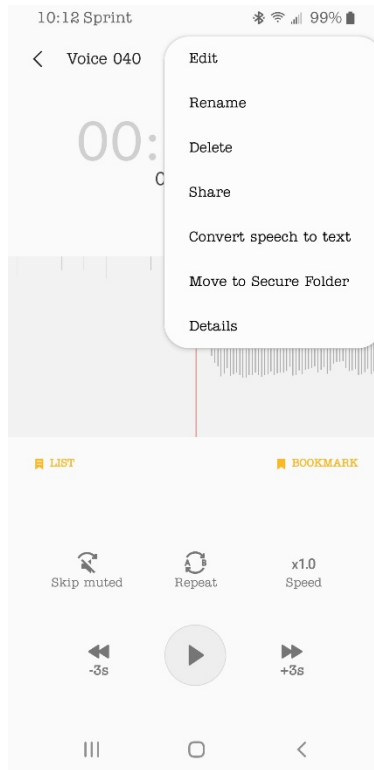


Figure 19: Recording Options

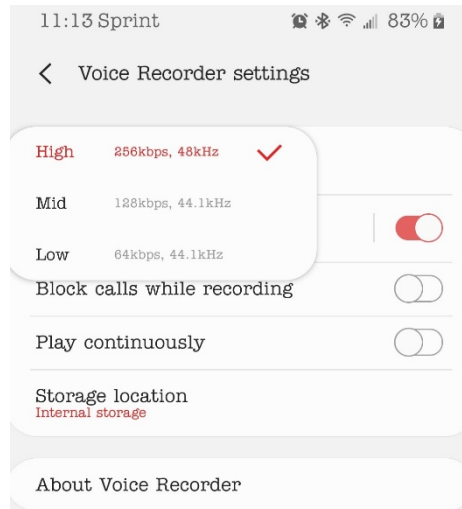


Figure 20: File Format Options

Editing

The editing capabilities of the Voice Recorder for the S6 and the S9 offer the most options of all the recording apps tested. These phones offer the option to delete the beginning, the middle and the end of the recording. Once the recording is saved, the user can select “Edit” and then editing markers can be placed wherever needed (**Figure 21**).

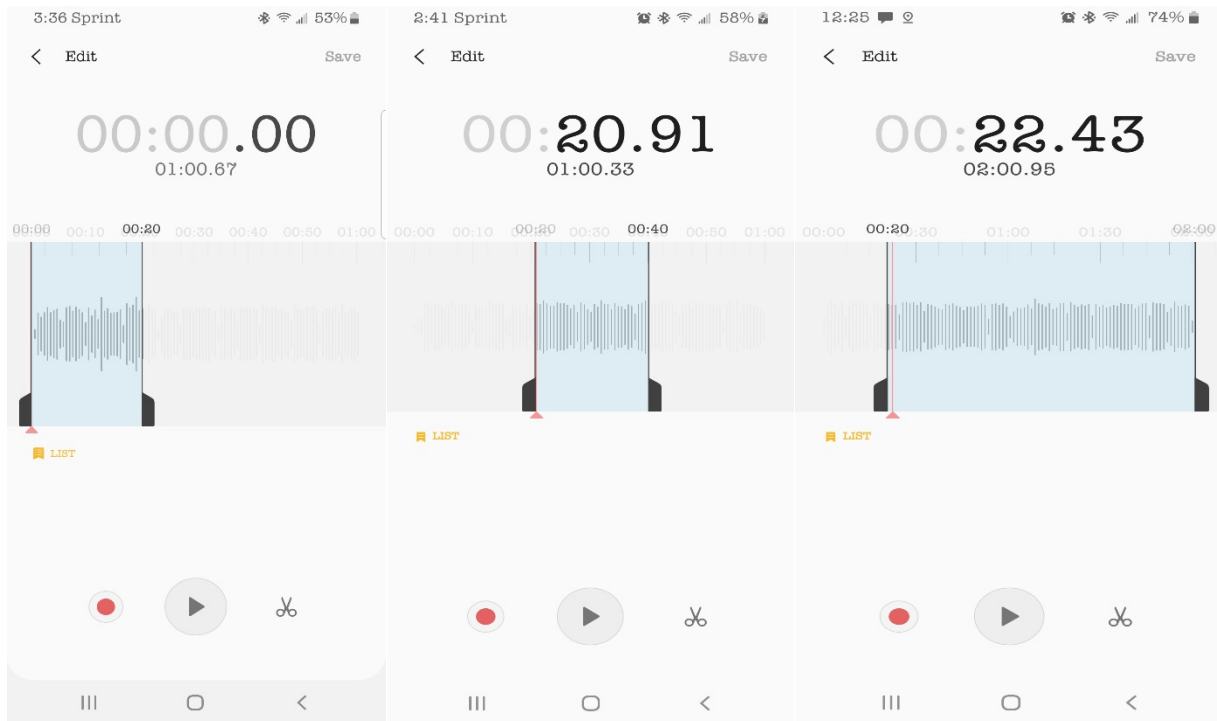


Figure 21: Editing Markers

The user then selects the scissors icon and has two options: “Delete selected area” and “Delete dimmed area”. If “delete dimmed area” is selected, the area that is barely visible will be deleted. In **Figure 22** the dimmed area is the beginning and the ending of the recording, so the area that is selected will be saved.

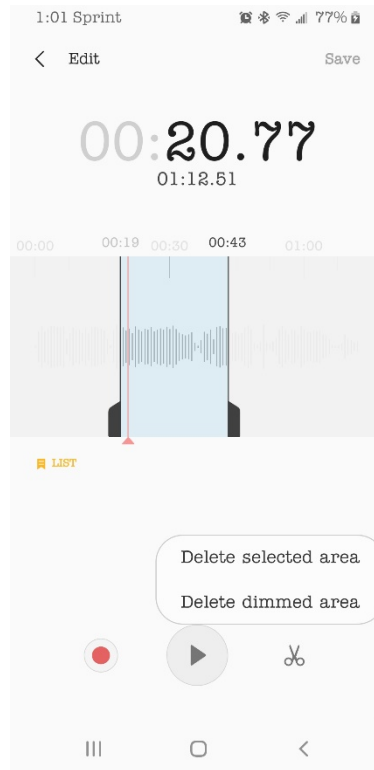


Figure 22: Editing Options

If the middle of a recording is deleted, then the beginning and ending are spliced together. If the middle of the recording is selected, then the beginning and ending are deleted; however, a section cannot be cut and pasted in the recording or into another recording. When editing is completed, the file can either be saved as a new file or an overwrite of the original recording.

Any section of the recording including the whole recording can be recorded over and it can either be saved as a new recording or an overwrite of the original recording. Like the original recording, any recording, even a partial overwrite, can be done in any format; it does not have to be the same as the original recording. If the recording is overwritten, the original no longer exists. If a recording is deleted, it disappears from the

app. (It is unknown whether the phone retains the audio recording or not, that was outside the scope of this paper.)

Interrupted Recordings with Phone Calls

Since the S9 had service at the time of testing, recordings were made with an interruption of an incoming call from another mobile phone. The first recording received a phone call, but the call was ignored. The Voice Recording did not pause or stop if the phone call was ignored; however, a vibrating noise is recorded in the audio.

Another recording was made with an interrupting phone call and this time the call was answered. The Voice Recorder paused the recording as soon as the call was answered and then resumed automatically once the call ended. It did not record any of the conversation.

CHAPTER III

TEST RECORDING PROTOCOL

A testing protocol, developed by Jeff Smith, et al. for the iOS in “Triage Approach for the Forensic Analysis of Apple iOS Audio Files Recorded Using the ‘Voice Memos’ App” [4] was later expanded by Hill for his thesis, “Analysis of Audio Recordings made using ‘Voice Memos’ application for iOS” [5]. Hill’s thesis protocol offered a skeleton of protocols to start with; but since the Android OS and the iOS are very different in form and function, a proper protocol had to be created for the Android OS. Since the HTC One had such limited capabilities, a protocol was not established; and since the S6 and S9 were identical in abilities, those two phones were combined to create the protocol for those Android versions.

LG Q6

Since this version of the Voice Recorder offered options for recording and editing, it was important to ensure that all recording options as well as editing options were explored; therefore, a testing protocol was established. It was important to see what artifacts were introduced into the recording by Android when the user accesses all available options for recording and editing.

In view of the fact that there was only one quality setting for the audio, different recordings were completed as continuous or paused and either saved on the device or on the external storage card. The editing section allows the user to trim the beginning, ending or both for whatever desired amount of time. Additional recordings were created and then later edited and saved as overwritten recordings. All original, edited and overwritten recordings were transferred to the computer using a USB cable.

Samsung S6 and S9

As previously stated in Chapter 2, the S6 and S9 had three quality settings all of which could be done in mono or stereo: low quality, mid quality and high quality; therefore, each set of recordings had to be completed in each quality setting, including all edited recordings. Like the Q6, continuous and paused recordings were created. A protocol was created to “stop” and “save” immediately after recording and “stop” is pressed and “save” is pressed one minute later. Later, original recordings were changed by recording over a portion of the recording and then saved as an overwritten file. Recordings were also trimmed from the beginning, end, both, and deleted sections of the middle of the recordings. Each edit was done on each quality setting.

The S9 had service during the testing period so recordings were made with interruptions from incoming calls as well. One protocol was to ignore the call, the other protocol was to answer the call.

All recordings from the S6 and the S9 were transferred to the computer using a USB and USB-C cable respectively.

CHAPTER IV

RESULTS

All phones – except for the HTC One - complied to the QuickTime File Format Specification [7]. **Figure 23** is an example of a movie atom structure showing the breakdown of the moov atom and what order the atoms are in. Each voice recording - again with the exception of the HTC One – followed this structure.

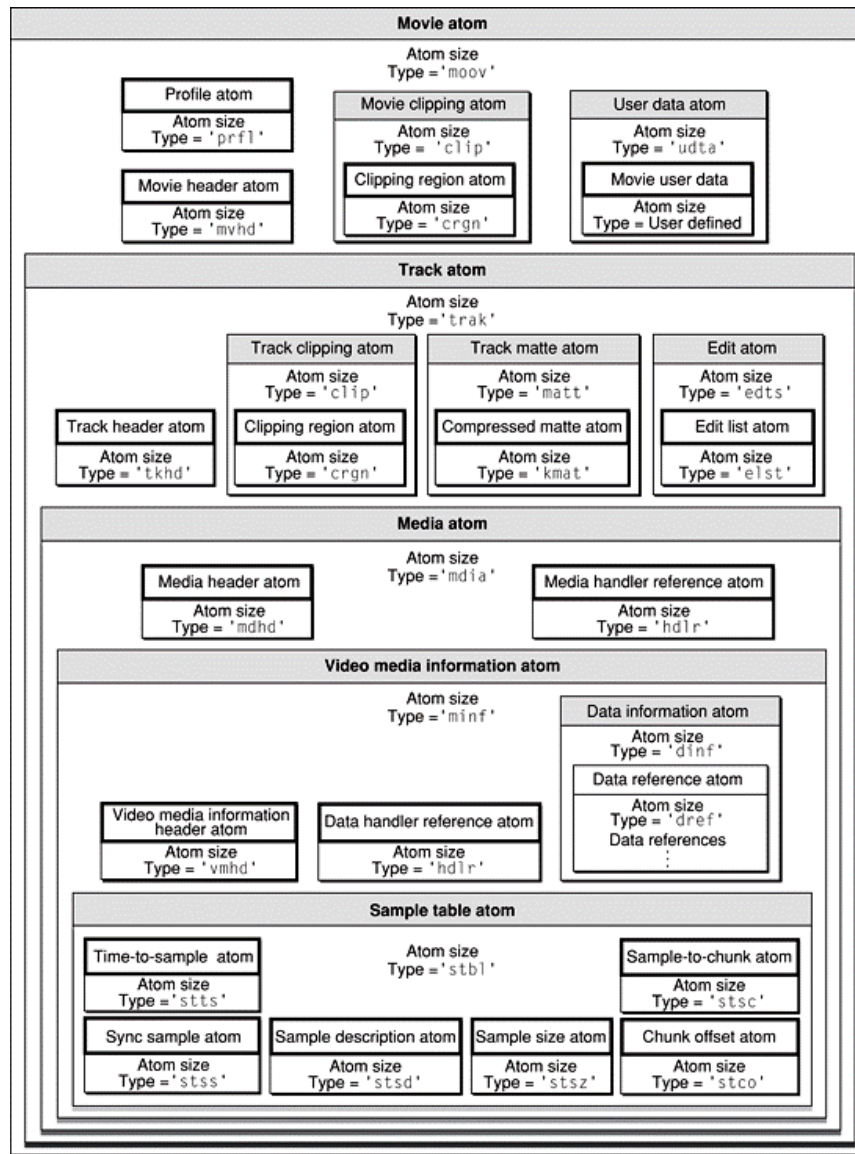


Figure 23: QuickTime File Format Movie Atom Example

While the S6 and S9 were almost exactly the same in Voice Recorder app and all the features that it offered, when it came to the results that were found, they actually differed on a few things. Therefore, each phone will be listed separately with the results that were found.

Device #1: HTC One

The HTC One revealed a minimal amount of results. One key factor noted from the very beginning was the inability to edit directly on the app. The encoding of the audio is also limited to AMR-NB, AMR-WB and AAC-LC. It is possible to take a recording from the phone, download it to the computer and then edit it from a third-party editor. As long as the new audio file is saved as an AAC, it is possible to then upload the audio recording back onto the app. For this paper the editing was done in Adobe Audition [8] and saved as AAC. (Any other format was not able to upload and be accessible in the app on the phone.) This new recording was then downloaded from the computer into the Voice Recorder folder on the phone. On the user interface there was no visible difference between this new edited recording and the other original recordings.

When the edited recording was downloaded back onto the app, there was no visible difference between that one and others that were directly recorded on the phone (**Figure 24**). The date displayed is the date that the audio was downloaded onto the phone from the computer after it had been edited in Adobe Audition. In the list of recordings, it is listed at the top since it was the most recent recording, but there is nothing else visually that sets it apart from any of the other recordings.

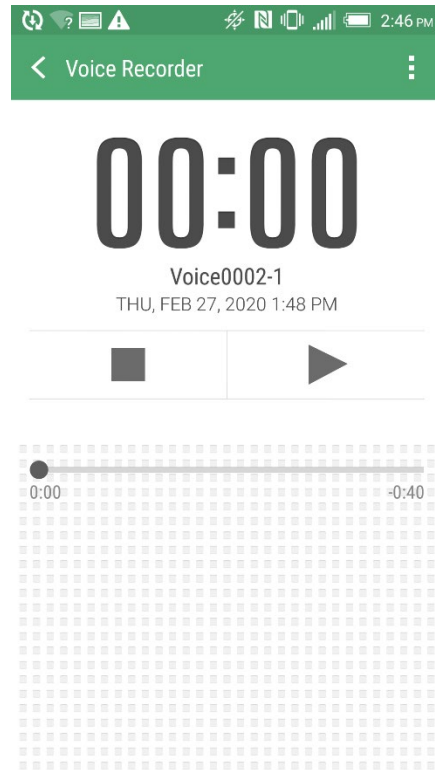


Figure 24: Edited Audio in Voice Recorder

The recordings on this device also contained a minimal amount of metadata. When looked at through a hex editor like 010 Editor [9], most of the data was raw audio data, including the AAC recordings (**Figure 25, Figure 26, Figure 27**). Therefore, there was no atom structure to examine.

0000h:	p3 21 41 4D 52 0A 3C E0 6D 64 8C 44 F3 81 88 81	#!AMR.<àmdCEDó.^.
0010h:	4F 3F D1 16 15 47 80 00 03 91 BE 99 41 18 00 00	O?Ñ..G€.. 'M'A...
0020h:	0E FE 44 41 62 00 3C B5 16 90 9A C1 50 00 60 1F	.pDAb.<µ..šÁP.`.

Figure 25: AMR-NB Hex Data

0000h:	p3 21 41 4D 52 2D 57 42 0A 3C 31 46 01 71 E2 0B	#!AMR-WB.<1F.qâ.
0010h:	17 91 42 11 ED 84 46 7F D5 5C 05 18 46 76 EC 02	. 'B.í„F.Ö\...Fvì.

Figure 26: AMR-WB Hex Data

0000h:	FF F1 4C 40	2B 9F FC 01	40 22 80 A3	7F F8 85 2D	ÿñL@+ÿü.@"€£.ø...-
0010h:	2D 2D 2D 2D	2D 2D 2D 2D	2D 2D 2D 2D	2D 2D 2D 2D	-----
0020h:	2D 2D 2D 2D	2D 2D 2D 2D	2D 2D 2D 2D	2D 2D 2D 2D	-----
0030h:	2D 2D 2D 2D	2D 2D 2D 2D	2D 2D 2D 2D	2D 2D 2D 2D	-----
0040h:	2D 2D 2D 2D	2D 2D 2D 2D	2D 2D 2D 2D	2D 2D 2D 2D	-----
0050h:	2D 2D 2D 2D	2D 2D 2D 2D	2D 2D 2D 2D	2D 2D 2D 2D	-----
0060h:	2D 2D 2D 2D	2D 2D 2D 2D	2D 2D 2D 2D	2D 2D 2D 2D	-----
0070h:	2D 2D 2D 2D	2D 2D 2D 2D	2D 2D 2D 2D	2D 2D 2D 2D	-----
0080h:	2D 2D 2D 2D	2D 2D 2D 2D	2D 2D 2D 2D	2D 2D 2D 2D	-----
0090h:	2D 2D 2D 2D	2D 2D 2D 2D	2D 2D 2D 2D	2D 2D 2D 2D	-----
00A0h:	2D 2D 2D 2D	2D 2D 2D 2D	2D 2D 2D 2D	2D 2D 2D 2D	-----
00B0h:	2D 2D 2D 2D	2D 2D 2D 2D	2D 2D 2D 2D	2D 2D 2D 2D	-----
00C0h:	2D 2D 2D 2D	2D 2D 2D 2D	2D 2D 2D 2D	2D 2D 2D 2D	-----
00D0h:	2D 2D 2D 2D	2D 2D 2D 2D	2D 2D 2D 2D	2D 2D 2D 2D	-----
00E0h:	2D 2D 2D 2D	2D 2D 2D 2D	2D 2D 2D 2D	2D 2D 2D 2D	-----
00F0h:	2D 2D 2D 2D	2D 2D 2D 2D	2D 2D 2D 2D	2D 2D 2D 2D	-----
0100h:	2D 2D 2D 2D	2D 2D 2D 2D	2D 2D 2D 2D	2D 2D 2D 2D	-----
0110h:	2D 2D 2D 2D	2D 2D 2D 2D	2D 2D 2E F3	11 0A 5A 5A	-----..ó..ZZ
0120h:	5A 5A 5A 5A	5A 5A 5A 5A	5A 5A 5A 5A	5A 5A 5A 5A	ZZZZZZZZZZZZZZZZZZ
0130h:	5A 5A 5A 5A	5A 5A 5A 5A	5A 5A 5A 5A	5A 5A 5A 5A	ZZZZZZZZZZZZZZZZZZ
0140h:	5A 5A 5A 5A	5A 5A 5A 5A	5A 5A 5A 5A	5A 5A 5A 5A	ZZZZZZZZZZZZZZZZZZ
0150h:	5A 5A 5A 5A	5A 5A 5A 5A	5A 5A 5A 5E	FF F1 4C 40	ZZZZZZZZZZ^ÿñL@
0160h:	2B 9F FC 00	EC 35 2D 10	96 2B 94 1A	82 74 15 15	+ÿü.ì5-.-+".,t..
0170h:	52 92 95 32	D9 7B 21 AD	28 B3 C3 C1	0F 01 3C AC	R'•2Û{!-('ÁÁ..<-
0180h:	55 D1 0E 1B	9E A1 21 10	5B F3 61 02	9B 70 10 29	UÑ..ž;!. [óa. »p.)
0190h:	36 21 01 02	9C 20 00 F7	07 F1 1F 0F	9D 9F AD E1	6!..ø .÷.ñ...ÿ-á
01A0h:	17 B7 19 72	E3 CB B2 B5	AE AC 9E 05	19 22 5A B4	. .rãĚ°µ@-ž.."Z´
01B0h:	4A 6E BD 86	D4 84 C9 18	80 18 BA 87	A3 33 56 AB	Jn†+Ô„É.€.°+£3V«
01C0h:	23 01 45 88	8E F9 AA A2	54 CD 55 6E	9C C3 08 CD	#.E^Žù°¢TíUnœĂ.Í
01D0h:	9F E3 7F 8B	9F 53 22 58	50 10 A0 67	22 52 14 08	Ÿă.<ŸS"XP. g"R..
01E0h:	A9 8B 04 56	EC 18 82 52	1F A8 71 05	3B EF BA 10	©<.Vi.,R. "q.;i°.

Figure 27: AAC Hex Data

However, the atom structure for the recording edited in Adobe Audition and then downloaded back into the app, gave very different information. The header and footer information viewed in a hex editor revealed all the information of the file from Adobe and how it was saved as a file. This atom structure followed the QuickTime File Format and immediately the header of the file gave different metadata from the original recording (Figure 28).

0000h:	00 00 00 18	66 74 79 70	6D 70 34 32	00 00 00 00ftypmp4....
0010h:	6D 70 34 31	69 73 6F 6D	00 00 00 28	75 75 69 64	mp4lisom...(uuid
0020h:	5C A7 08 FB	32 8E 42 05	A8 61 65 0E	CA 0A 95 96	\\$.û2ŽB."ae.Ê.·-
0030h:	00 00 00 0C	31 30 2E 30	2E 31 37 37	36 33 2E 3010.0.17763.0
0040h:	00 0A 08 5F	6D 64 61 74	00 00 00 00	00 00 00 10	...mdat.....
0050h:	07 10 18 A8	50 26 1C 05	02 C1 81 30	60 2C 28 23	...P&...Á.0`,(#

Figure 28: Header Information in Hex Editor

In the footer information of the hex, Adobe Audition is specifically listed (**Figure 29**). It also shows that the file was from a Windows version of Audition. Since this hex information varies so much from an original recording on the HTC One, an examiner can easily assess that this recording cannot be original to the phone.

A:3330h:	31 66 32 36	66 31 36 22	0A 20 20 20	20 20 20 73	1f26f16". s
A:3340h:	74 45 76 74	3A 77 68 65	6E 3D 22 32	30 32 30 2D	tEvt:when="2020-
A:3350h:	30 32 2D 32	37 54 31 33	3A 34 38 3A	33 35 2D 30	02-27T13:48:35-0
A:3360h:	37 3A 30 30	22 0A 20 20	20 20 20 20	73 74 45 76	7:00". stEv
A:3370h:	74 3A 73 6F	66 74 77 61	72 65 41 67	65 6E 74 3D	t:softwareAgent=
A:3380h:	22 41 64 6F	62 65 20 41	75 64 69 74	69 6F 6E 20	"Adobe Audition
A:3390h:	31 33 2E 30	20 28 57 69	6E 64 6F 77	73 29 22 0A	13.0 (Windows)".
A:33A0h:	20 20 20 20	20 20 73 74	45 76 74 3A	63 68 61 6E	stEvt:chan
A:33B0h:	67 65 64 3D	22 2F 6D 65	74 61 64 61	74 61 22 2F	ged="/metadata/"

Figure 29: Footer Information

Device #2: LG Q6

Consistencies and Inconsistencies

Following the testing protocol, it was important to see what information is consistent and inconsistent across the different types of recordings. All bit rates and sample rates remained the same regardless of whether the recording was continuous, paused, edited or overwritten. The Android version – 7.1.1 – and the phone model number – LG-US700 - were also listed in the header and footer of the metadata, depending on whether it was an unedited or edited recording. For all continuous or paused unedited recordings the metadata was contained in the header of the file. For edited or overwritten continuous or paused recordings, the metadata was contained in the footer of the file.

Atom Structure

For unedited recordings, the metadata is contained in the header and the media data (mdat) atom is at offset 0x62E9F. This was consistent for all unedited recordings, whether continuous or paused. However, for continuous/paused edited/overwritten recordings the metadata is contained in the footer and the mdat atom is at offset 0xC97. This structure change shows that something is different between the unedited and edited/overwritten recordings. Also, in edited and overwritten recordings a “free” atom is contained in the header. This is another indication that something has changed from an unedited recording.

Table 3: Comparison of Unedited and Edited Recordings on the Q6

LG Q6			
	UNEDITED	EDITED/ OVERWRITTEN	RESULTS
BITE RATE	96 kbps	96 kbps	CONSISTENT
SAMPLE RATE	44.1 kHz	44.1 kHz	CONSISTENT
ANDROID VERSION	LISTED	LISTED	CONSISTENT
"PHONE MODEL"	LISTED	LISTED	CONSISTENT
MDAT ATOM AT OFFSET	0x62E9F	0xC97	INCONSISTENT
METADATA LOCATION	HEADER	FOOTER	INCONSISTENT
HEADER OF FILE	METADATA	"FREE"	INCONSISTENT

Device #3: Samsung S6

Consistencies and Inconsistencies

There were many similarities between the unedited and edited recordings, regardless of whether they were continuous or paused recordings. The sample rate and bit rate remained the same and there was no “Android app” listed and no “Voice Recorder” listed in the metadata.

However, in unedited recordings the Android version is listed in the metadata but not in the edited versions. This was true for continuous and paused recordings, regardless of whether the recordings were edited or overwritten.

Atom Structure

The mdat atom was located at offset 0x1C for both edited and unedited recordings, and all metadata was contained in the footer. The headers of the files were also very different at first glance. **Figure 30** displays how the header of an unedited recording contains some basic file information: file type, iso_media file format, and the mdat atom followed by many repeated bytes, i.e., 0x2D, 0x5A, 0xB4.

0000h:	00 00 00 18	66 74 79 70	33 67 70 34	00 00 00 00ftyp3gp4....
0010h:	69 73 6F 6D	33 67 70 34	00 07 89 53	6D 64 61 74	isom3gp4..%Smdat
0020h:	01 40 22 80	A3 7D 20 85	2D 2D 2D 2D	2D 2D 2D 2D	.@"€} ...-----
0030h:	2D 2D 2D 2D	2D 2D 2D 2D	2D 2D 2D 2D	2D 2D 2D 2D	-----
0040h:	2D 2D 2D 2D	2D 2D 2D 2D	2D 2D 2D 2D	2D 2D 2D 2D	-----
0050h:	2D 2D 2D 2D	2D 2D 2D 2D	2D 2D 2D 2D	2D 2D 2D 2D	-----
0060h:	2D 2D 2D 2D	2D 2D 2D 2D	2D 2D 2D 2D	2D 2D 2D 2D	-----
0070h:	2D 2D 2D 2D	2D 2D 2D 2D	2D 2D 2D 2D	2D 2D 2D 2D	-----
0080h:	2D 2D 2D 2D	2D 2D 2D 2D	2D 2D 2D 2D	2D 2D 2D 2D	-----
0090h:	2D 2D 2D 2D	2D 2D 2D 2D	2D 2D 2D 2D	2D 2D 2D 2D	-----
00A0h:	2D 2D 2D 2D	2D 2D 2D 2D	2D 2D 2D 2D	2D 2D 2D 2D	-----
00B0h:	2D 2D 2D 2D	2D 2D 2D 2D	2D 2D 2D 2D	2D 2D 2D 2D	-----
00C0h:	2D 2D 2D 2D	2D 2D 2D 2D	2D 2D 2D 2D	2D 2D 2D 2D	-----
00D0h:	2D 2D 2D 2D	2D 2D 2D 2D	2F 01 40 22	80 A3 7D 28	-----/."€} (

Figure 30: Hex Data Header of Unedited Recording

While **Figure 31** displays how the header of an edited recording also contains the file type, iso_media file format and mdat atom, this information is followed by raw audio data.

0000h:	p0 00 00 18	66 74 79 70	33 67 70 34	00 00 00 00ftyp3gp4....
0010h:	69 73 6F 6D	33 67 70 34	00 05 10 08	6D 64 61 74	isom3gp4....mdat
0020h:	01 28 34 2C	D4 84 33 0C	86 C1 80 A9	4C EC FB 4C	. (4,Ô,,3.+Áæ@LiûL
0030h:	D5 71 C5 35	72 44 2A 22	55 21 A5 00	36 1C BE 99	ÔqÂ5rD*"U!¥.6.¼
0040h:	EC 9F AC C9	7B 1F AD 33	CD 12 0E 30	C1 C1 4B F8	ìÿ-É{-3Í..0ÁÁKø
0050h:	37 1E 95 97	3D AF DB 3D	CB 3A A1 1F	6C 10 DD 76	7.*-=-Û=È:;.1.Ýv
0060h:	C2 65 68 CF	D3 66 91 A4	A2 13 92 7D	E5 00 DC 07	ÂehİÓf'xc.'}â.Û.
0070h:	3D C8 AB 34	09 17 99 D7	B6 60 08 96	FB 21 DA 85	=È«4..¼×q`.-û!Û...
0080h:	00 E6 8D 40	2B D5 82 F2	B2 EE EB D4	08 74 20 1B	.æ. @+Ô, ò²iëÔ.t .
0090h:	26 0B A1 22	72 64 40 75	84 20 59 52	7D 9F 3F DD	&.;"rd@u,, YR)ÿ?ÿ
00A0h:	FF CE 37 DB	37 89 41 11	00 A8 4D C4	F3 E8 FB 3C	ÿİ7Û7%A..MÃóèû<
00B0h:	A3 3D 5D 04	01 60 02 75	A2 4B F8 7B	7A 3E 3D 1B	f=]..`.ucKø{z>=.
00C0h:	5A 40 05 6E	68 A8 ED 2B	2D 19 24 DD	5D 96 D3 0B	Z@.nh"i+-.\$ÿ]-Ô.
00D0h:	DA D6 8A C3	2F DD 40 1C	01 2C 34 2C	B4 E6 29 0D	ÛÔŠÃ/ÿ@...4, 'æ).
00E0h:	88 82 13 B7	EF 7D 6F 4B	5D 6A E6 92	AA AA 5D 4A	^,..i}oK]jæ'²²]J

Figure 31: Hex Data Header of Edited Recording

So even though there are many consistencies between the unedited and edited recordings, there are differences between the two as shown in **Table 4**.

Table 4: Comparison of Unedited and Edited Recordings on the S6

SAMSUNG S6			
	UNEDITED	EDITED/ OVERWRITTEN	RESULTS
BITE RATE	USER DETERMINED	SAME	CONSISTENT
SAMPLE RATE	USER DETERMINED	SAME	CONSISTENT
"ANDROID APP"	NOT LISTED	NOT LISTED	CONSISTENT
"VOICE RECORDER"	NOT LISTED	NOT LISTED	CONSISTENT
MDAT ATOM AT OFFSET	0x1C	0x1C	CONSISTENT
METADATA LOCATION	FOOTER	FOOTER	CONSISTENT
ANDROID VERSION	LISTED	NOT LISTED	INCONSISTENT
HEADER OF FILE	METADATA & REPEATED RAW AUDIO BYTES	METADATA & RANDOM RAW AUDIO BYTES	INCONSISTENT

Device #4: Samsung S9

Consistencies and Inconsistencies

As stated earlier, the S6 and S9 were very similar but the results differed a bit. On the S9, “Android app” and “Voice Recorder” were listed in the metadata of the file. This is where the S6 and S9 differed. The S6 did not list “Android app” or “Voice Recorder” while the S9 did. This was the only area where they were different. Even though the Android versions are different and the Voice Recorder versions are different, the user interface is the same. So, to find something that was different in the metadata between the two was unexpected.

On the S9 the bit rate and sample rate remained the same regardless of whether the recording was continuous or paused, edited or unedited. The “Android app” and “Voice Recorder” were also listed in both unedited and edited recordings.

One difference observed between the unedited and edited recordings was that the Android version is listed in the metadata for the unedited recordings, while the Android version is not listed in the edited or overwritten recordings.

Atom Structure

For both unedited and edited/overwritten recordings, the mdat atom is located at offset 0x1C. The metadata for both is also included in the footer of the file; however, like the S6, the header information is different between unedited and edited/overwritten recordings. Consistent with the S6, the header of an unedited recording contains some basic file information, file type, iso_media file format, and the mdat atom followed by many repeated bytes, i.e., 0x2D, 0x5A and 0xB4. The header for an edited/overwritten recording contains the file type, iso_media file format and mdat atom,

and then this information is followed by raw audio data. **Table 5** summarizes the consistencies and inconsistencies between the unedited and edited/overwritten recordings. Again, whether the recording was continuous or paused, the atom structure remains the same.

Table 5: Comparison of Unedited and Edited Recordings on the S9

SAMSUNG S9			
	UNEDITED	EDITED/ OVERWRITTEN	RESULTS
BITE RATE	USER DETERMINED	SAME	CONSISTENT
SAMPLE RATE	USER DETERMINED	SAME	CONSISTENT
"ANDROID APP"	LISTED	LISTED	CONSISTENT
"VOICE RECORDER"	LISTED	LISTED	CONSISTENT
MDAT ATOM AT OFFSET	0x1C	0x1C	CONSISTENT
METADATA LOCATION	FOOTER	FOOTER	CONSISTENT
ANDROID VERSION	LISTED	NOT LISTED	INCONSISTENT
HEADER OF FILE	METADATA & REPEATED AUDIO BYTES	METADATA & RAW AUDIO BYTES	INCONSISTENT

CHAPTER V

CONCLUSION

Each phone with its different Android versions and different app versions offered different results based upon whether the recording was edited or unedited, continuous or paused. All of which contain important information when it comes to the analysis of these recordings and the authenticity of these recordings as related to each phone. Given that each phone comprises different user interfaces and different results, it's important for investigators to be aware of the features and limitations for each app. The consistencies between edited and unedited recordings also supply examiners with much needed information. There are many other aspects of the Voice Recorder app to research, but this paper provides a plethora of information that was not available before.

Future Research

There are many phones on the market that need to be tested. Motorola and Nokia phones do not have a default voice recorder app, but they are different versions of Android and can have different artifacts than the phones tested for this paper. There are also many third-party voice recorders available from Google Play that also may have different artifacts from the apps tested for this paper. All of them need research. The speech-to-text option on the Voice Recorder app for the Samsung phones also needs research. The dates and times of the recordings need to be thoroughly investigated on each phone as well.

Different devices, such as tablets, also have the capability to record audio. The "Memo's" application that comes on Android phones and tablets also has the ability to record audio. There may be enough similarities between them all that further research is not necessary, but this is unknown at this time.

The Android OS, like the iOS, will always be updating with new features and abilities. The Voice Recorder app will also go through updating and possibly a total refresh to the app. These new developments will need to be studied.

There are also audio recording apps available that can record a phone call. These, too, need research. It is important to keep in mind with this type of recording that state laws are taken into consideration. In some states only one party needs to be aware that the conversation is being recorded, while others require that both parties know and consent to having the conversation recorded.

REFERENCES

1. Callaham, J. *The History of Android OS: its name, origin and more*. 2019 August 18, 2019 [cited 2019 August 18, 2019]; Available from: <https://www.androidauthority.com/history-android-os-name-789433/>.
2. O'Dea, S. *Android OS market share of smartphone sales to end users from 2009-2018*. 2020 Feb. 28, 2020; Available from: <https://www.statista.com/statistics/216420/global-market-share-forecast-of-smartphone-operating-systems/>.
3. Hoog, A., *Android Forensics*. 2011: Syngress.
4. Smith, J., et al., *Triage Approach for the Forensic Analysis of Apple iOS Audio Files Recorded Using the "Voice Memos" App*, in *2017 International Conference on Audio Forensics*. 2017, AES: Arlington, VA. p. 1-5.
5. Hill, A., *ANALYSIS OF AUDIO RECORDINGS MADE USING "VOICE MEMOS" APPLICATION FOR iOS*, in *College of Arts and Media*. 2017, University of Colorado Denver: National Center for Media Forensics.
6. Scientific Working Group on Digital Evidence, *SWGDE Digital and Multimedia Evidence Glossary*. 2016 6/23/2016 9/13/2019]; Available from: <https://www.swgde.org/documents/Current%20Documents/SWGDE%20Digital%20and%20Multimedia%20Evidence%20Glossary>.
7. *QuickTime File Format Specification*. 2016 9-12-2016 Feb. 15, 2019]; Available from: <https://developer.apple.com/library/archive/documentation/QuickTime/QTFF/QTFFPreface/qtffPreface.html>.
8. Adobe, *Adobe Audition*. adobe.com.
9. *010 Editor*. Sweetscape Software.

APPENDIX A

TEST RECORDING COLLECTION PROTOCOL FOR LG Q6

PROPOSED LG Q6 "AUDIO RECORDER" TEST RECORDING PROTOCOL				
SEQUENCE OF TEST RECORDINGS [DEVELOPED WITH Q6, OS 7.1.1, APP VERSION 6.1.8]				
STATE	#	DESCRIPTION	EXPECTED OUTCOME	REASON(S)
Continuous	1	Continuous 1-minute recording with "stop" pressed as quickly as possible at the end of the recording; saved with default name.	96 kbps, 44.1kHz mono MPEG 4	Time characteristics of stop/pause events
	2			
	3			
	4	Continuous 1-minute recording with "stop" pressed as quickly as possible at the end of the recording; saved with default name. (These will be overwritten in editing).		
	5			
	6			
Discontinuous	7	1-minute recording, press "pause" and leave for 2-minutes; press "record" and leave for one additional minute then "stop" to end recording; save with default name.		
	8			
	9			
	10	1-minute recording, press "pause" and leave for 2-minutes; press "record" and leave for one additional minute then "stop" to end recording; save with default name. (These will be overwritten in editing).		
	11			
	12			
DOWNLOAD TEST RECORDINGS 1 → 12				

PROPOSED LG Q6 "AUDIO RECORDER" TEST RECORDING PROTOCOL

SEQUENCE OF TEST RECORDINGS [DEVELOPED WITH Q6, OS 7.1.1, APP VERSION 6.1.8]

STATE	#	DESCRIPTION	EXPECTED OUTCOME	REASON(S)
Altered (new file)	13	At least one day after the initial test recording of one continuous minute, click the scissors icon (editing) and move start point to 20-second point so that the recording length is now approx. 40 seconds (deleting the first 20 seconds of the recording). Then click on check icon. Select to save as new file (not overwrite the original recording), save with default name.	96 kbps, 44.1kHz mono MPEG 4	Metadata/file structure, evidence of editing
	14	At least one day after the initial test recording of one continuous minute, click the scissors icon (editing) and move end point to 20-seconds so that the recording length is now approx. 40 seconds (deleting the last 20 seconds of the recording). Then click on check icon. Select to save as new file (not overwrite the original recording), save with default name.		
	15	At least one day after the initial test recording of one continuous minute, click the scissors icon (editing) and move start point to 20-seconds and end point to 40-seconds so that the recording length is now approx. 20 seconds (deleting the first 20 seconds and the last 20 seconds of the recording). Then click on check icon. Select to save as new file (not overwrite the original recording), save with default name.		

PROPOSED LG Q6 "AUDIO RECORDER" TEST RECORDING PROTOCOL

SEQUENCE OF TEST RECORDINGS [DEVELOPED WITH Q6, OS 7.1.1, APP VERSION 6.1.8]

STATE	#	DESCRIPTION	EXPECTED OUTCOME	REASON(S)
Altered and Discontinuous (new file)	16	At least one day after the initial test recording of discontinuous minutes, click the scissors icon (editing) and move start point to 20-second point so that the recording length is now approx. 1 minute, 40 seconds (deleting the first 20 seconds of the recording). Then click on check icon. Select to save as new file (not overwrite the original recording), save with default name.	96 kbps, 44.1kHz mono MPEG 4	Metadata/file structure, evidence of editing
	17	At least one day after the initial test recording of discontinuous minutes, click the scissors icon (editing) and move end point to 20-seconds so that the recording length is now approx. 1 minute 40 seconds (deleting the last 20 seconds of the recording). Then click on check icon. Select to save as new file (not overwrite the original recording), save with default name.		
	18	At least one day after the initial test recording of discontinuous minutes, click the scissors icon (editing) and move start point to 20-seconds and end point to 20 seconds so that the recording length is now approx. one minute 40 seconds (deleting the first 20 seconds and the last 20 seconds of the recording). Then click on check icon. Select to save as new file (not overwrite the original recording), save with default name.		

PROPOSED LG Q6 "AUDIO RECORDER" TEST RECORDING PROTOCOL

SEQUENCE OF TEST RECORDINGS [DEVELOPED WITH Q6, OS 7.1.1, APP VERSION 6.1.8]

STATE	#	DESCRIPTION	EXPECTED OUTCOME	REASON(S)
Overwrite continuous	19	Continuous 1-minute recording with "stop" pressed as quickly as possible at the end of the recording (original), edit recording and choose "overwrite" option and give new name.	96 kbps, 44.1kHz mono MPEG 4	Metadata/file structure, evidence of editing
	20			
Overwrite discontinuous	21	1-minute recording, press "pause" and leave for 2-minutes; press "record" and leave for one additional minute then "stop" to end recording (original), edit recording and choose "overwrite" option and give new name.	96 kbps, 44.1kHz mono MPEG 4	Metadata/file structure, evidence of editing
	22			
DOWNLOAD TEST RECORDINGS 13 → 22				

APPENDIX B

TEST RECORDING COLLECTION PROTOCOL FOR SAMSUNG S6 AND S9

PROPOSED SAMSUNG S6 AND S9 "VOICE RECORDER" TEST RECORDING PROTOCOL					
SEQUENCE OF TEST RECORDINGS [DEVELOPED WITH S6 & S9 ANDROID 7 & 10, APP VERSIONS 20.1.83-16, 21.2.00.42]					
STATE	#	SETTINGS	DESCRIPTION	EXPECTED OUTCOME	REASON(S)
Continuous	1→2	Low quality - 64 kbps, 44.1kHz, mono & stereo	Continuous 1-minute recording with "stop" and "save" pressed as quickly as possible at the end of the recording; saved with default name. (Additional recordings created for overwrite option).	consistent quality settings for each recording MAC Information	Time characteristics of stop/pause events metadata for storage on SD card
	3→4	Mid quality - 128kbps, 44.1kHz, mono & stereo			
	5→6	High quality - 256kbps, 48kHz, mono & stereo			
	7→8	Low quality - 64 kbps, 44.1kHz, mono & stereo	Continuous 1-minute recording with "stop" pressed to end the recording, then "save" pressed one minute later. (Additional recordings created for overwrite option). Some recordings are saved on an external memory card.		
	9→10	Mid quality - 128kbps, 44.1kHz, mono & stereo			
	11→12	High quality - 256kbps, 48kHz, mono & stereo			

PROPOSED SAMSUNG S6 AND S9 "VOICE RECORDER" TEST RECORDING PROTOCOL

SEQUENCE OF TEST RECORDINGS [DEVELOPED WITH S6 & S9 ANDROID 7 & 10, APP VERSIONS 20.1.83-16, 21.2.00.42]

STATE	#	SETTINGS	DESCRIPTION	EXPECTED OUTCOME	REASON(S)
Discontinuous	13→14	Low quality - 64 kbps, 44.1kHz, mono & stereo	1-minute recording, press "pause" and leave for 2-minutes; press "record" and leave for one additional minute then "stop" to end recording; save with default name. (Additional recordings created for overwrite option). Some recordings are saved on an external memory card.	consistent quality settings for each recording MAC Information	Time characteristics of stop/pause events metadata for storage on SD card
	15→16	Mid quality - 128kbps, 44.1kHz, mono & stereo			
	17→18	High quality - 256kbps, 48kHz, mono & stereo			
	19→20	Low quality - 64 kbps, 44.1kHz, mono & stereo	1-minute recording, press "pause" and leave for 2-minutes; press "record" and leave for one additional minute then "stop" to end recording; press "save" one minute later with default name. (Additional recordings created for overwrite option). Some recordings are saved on an external memory card.		
	21→22	Mid quality - 128kbps, 44.1kHz, mono & stereo			
	23→24	High quality - 256kbps, 48kHz, mono & stereo			
	25	Mid quality - 128kbps, 44.1kHz, stereo	Continuous recording, received incoming call, but did not answer (let it go to voicemail), pressed "stop" and "save" at the end of the recording		
	26	High quality - 256kbps, 48kHz, stereo	Continuous recording, received incoming call, answered (noted call duration), pressed "stop" and "save" at the end of the recording		
DOWNLOAD TEST RECORDINGS 1 → 26					

PROPOSED SAMSUNG S6 AND S9 "VOICE RECORDER" TEST RECORDING PROTOCOL

SEQUENCE OF TEST RECORDINGS [DEVELOPED WITH S6 & S9 ANDROID 7 & 10, APP VERSIONS 20.1.83-16, 21.2.00.42]

STATE	#	SETTINGS	DESCRIPTION	EXPECTED OUTCOME	REASON(S)
Altered continuous (new file)	27→33	Low quality - mono & stereo Mid quality - mono & stereo High quality - mono & stereo	At least one day after the initial test recording of one continuous minute, click on "edit" and move start point to 20-second point so that the recording length is now approx. 40 seconds (deleting the first 20 seconds of the recording). Then click on scissors icon and select "delete dimmed area". Select to save as new file (not overwrite the original recording), save with default name.	consistent quality settings for each recording evidence of editing MAC Information	Metadata/file structure, evidence of editing
	34→40	Low quality - mono & stereo Mid quality - mono & stereo High quality - mono & stereo	At least one day after the initial test recording of one continuous minute, click the scissors icon (editing) and moved end point to 20-seconds so that the recording length is now approx. 40 seconds (deleting the last 20 seconds of the recording). Then click on check icon. Select to save as new file (not overwrite the original recording), save with default name.		
	41→47	Low quality - mono & stereo Mid quality - mono & stereo High quality - mono & stereo	At least one day after the initial test recording of one continuous minute, click the scissors icon (editing) and move start point to 20-seconds and end point to 40-seconds so that the recording length is now approx. 20 seconds (deleting the first 20 seconds and the last 20 seconds of the recording). Then click on check icon. Select to save as new file (not overwrite the original recording), save with default name.		

**PROPOSED SAMSUNG S6 AND S9 "VOICE RECORDER"
TEST RECORDING PROTOCOL**

**SEQUENCE OF TEST RECORDINGS [DEVELOPED WITH S6 & S9
ANDROID 7 & 10, APP VERSIONS 20.1.83-16, 21.2.00.42]**

STATE	#	SETTINGS	DESCRIPTION	EXPECTED OUTCOME	REASON(S)
Altered and Discontinuous (new file)	48→54	Low quality - mono & stereo Mid quality - mono & stereo High quality - mono & stereo	At least one day after the initial test recording of discontinuous minutes, click the scissors icon (editing) and move start point to 20-second point so that the recording length is now approx. 1 minute, 40 seconds (deleting the first 20 seconds of the recording). Then click on check icon. Select to save as new file (not overwrite the original recording), save with default name.	consistent quality settings for each recording evidence of editing MAC Information	Metadata/file structure, evidence of editing
	55→61	Low quality - mono & stereo Mid quality - mono & stereo High quality - mono & stereo	At least one day after the initial test recording of discontinuous minutes, click the scissors icon (editing) and move end point to 20-seconds so that the recording length is now approx. 1 minute 40 seconds (deleting the last 20 seconds of the recording). Then click on check icon. Select to save as new file (not overwrite the original recording), save with default name.		
	62→68	Low quality - mono & stereo Mid quality - mono & stereo High quality - mono & stereo	At least one day after the initial test recording of discontinuous minutes, click the scissors icon (editing) and move start point to 20-seconds and end point to 20 seconds so that the recording length is now approx. one minute 40 seconds (deleting the first 20 seconds and the last 20 seconds of the recording). Then click on check icon. Select to save as new file (not overwrite the original recording), save with default name.		

**PROPOSED SAMSUNG S6 AND S9 "VOICE RECORDER"
TEST RECORDING PROTOCOL**

**SEQUENCE OF TEST RECORDINGS [DEVELOPED WITH S6 & S9
ANDROID 7 & 10, APP VERSIONS 20.1.83-16, 21.2.00.42]**

STATE	#	SETTINGS	DESCRIPTION	EXPECTED OUTCOME	REASON(S)
Continuous Overwrite file	69→75	Low quality - mono & stereo Mid quality - mono & stereo High quality - mono & stereo	At least one day after the initial test recording of one continuous minute, select "edit" then "record" for 30 seconds, then "pause" to stop the new recording. Select "save" then select "replace original file".	consistent quality settings for each recording MAC Information	Metadata/file structure, evidence of overwriting
Discontinuous Overwrite file	76→82	Low quality - mono & stereo Mid quality - mono & stereo High quality - mono & stereo	At least one day after the initial test recording of one continuous minute, select "edit" then "record" for 30 seconds, then "pause" to stop the new recording. Select "save" then select "replace original file".		
DOWNLOAD ALTERED RECORDINGS 27→ 82					