A Psychotherapy Telemedicine System Using Sensory Substitution Feature for Audio-Based Interventions with Security Posture Evaluation

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***Abstract*—Telemedicine plays a significant role in today's modern doctor-patient consultation process. The use of disruptive technologies finds its way to provide medical intervention vehicles to make a diagnosis or treatment possible in a situation that face-to-face sessions will not be possible. Psychotherapy is a method used for psychological analysis for mental health services. It is an excellent opportunity to extend its advantages for both able and disable patients, especially for deaf patients. With the sensory substitution feature, deaf and mute patients can now experience an assistive teleconsultation system for their psychoanalysis need. This study developed a telemedicine system that focuses on psychoanalysis using binaural beats. This study also deals with the security posture of state-of-the-art telemedicine mobile applications to adequately address the vulnerability of such applications. Results show that passed usability results in terms of Nielsen's usability model from the perspective of mental health professionals and patients, both deaf and non-deaf users, the security posture of the developed telemedicine system is considered acceptable, based on standards.**

***Index Terms*—security posture evaluation, psychotherapy, telemedicine system, sensory substitution feature, binaural beats**

I. Introduction

Electronic health (e-Health) involves providing health services and exchanging health information through the Internet and related technologies. Telemedicine is known to be the first form of e-Health. Patient conferences, informative health pages, and self-tracking systems are Internet-based services [1]. Telemedicine has provided convenience and a low-cost way to access health services from the patient's perspective [2]. Based on a systematic review, entitled "Comparing the effectiveness of telemedicine and conventional psychotherapy in improving clinical outcomes of patients with depression" by Tan *et al.* [3], telemedicine – specifically telemental health interventions, are slightly better than conventional psychotherapy in treating patients with depression and their quality of life. According to a study entitled "Perceived benefits of psychotherapy via telemedicine based on suicide risk severity" by Ward-Ciesielski *et al.* [4], telemedicine had increased the patients' access to psychotherapy services.

Assistive Technology (AT) is a product or service that expands or extends an individual's capabilities [5]. The usage of AT provides opportunities for individuals to develop their well-being by maintaining and enhancing their performance and independence [6]. The study, entitled "Hearing through Vibrations: Perception of Musical Emotions by Profoundly Deaf People" by Schmitz *et al.*, was conducted to contribute to the field of AT for deaf individuals. The study also stated that new techniques of AT for deaf individuals are significant [7]. Web-based applications allow their users to receive services from the Internet through their mobile phones. The establishment of web-based mobile applications is ideal for allowing users to experience widespread compatibility and complete application portability [8]. Mental health applications are mostly mobile phone applications due it their accessibility [9].

Psychotherapy is considered a valid and legitimate treatment process [10]. Patients who require psychological treatment were able to gain access to psychotherapy services through online psychometric interventions. Multiple online psychotherapy methods are available online, such as interactive programs, online games, meditation applications, and online counseling [11]. A systematic review, entitled "Videoconferencing Psychotherapy and Depression: A Systematic Review" by Berryhill *et al.* [12], proved that online counseling through Videoconferencing Psychotherapy (VCP) is an effective method for providing mental health services.

Music can treat emotional-related cases such as anxiety. The usage of the effectiveness of music for the improvement of the well-being of an individual is considered a form of psychotherapy [13]. Binaural beats set the brain into a calm state. Because of this, they use it for psychological treatment [14].

This study identified disparities in the gathered related and existing systems available. There may be numerous references that focus on the development of telemedicine applications. However, to date, no study exists that combined the following functions in one system: used mood playlists feature for therapy accessible by both able and with impaired hearing users; used sensory substitution for enhancing the deaf user's musical

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experience for therapeutic purposes; the music substitution feature is into a telemedicine system with standard security implementation to ensure encrypted data transfer; the log feature intended for progress tracking and monitoring by a psychiatrist. This study aims to integrate audio interventions in a telemedicine system to establish a mental health service applied with risk assessment evaluation to protect its users and promote cybersecurity. There is a significant increase in telepresence and telemedicine during the pandemic and the growing need for equal and quality patient access to health care for both able and disabled patients, which will likely continue even after post-COVID-19 [15]. This study harnesses the benefits of video consultation in these trying times and further enhances its features, along with the development of an application with online risk assessment evaluation to protect its users and promote cybersecurity [16].

A. Objective of the Study

The main purpose of the study was to develop a psychotherapy telemedicine system with a sensory substitution feature for audio-based interventions. The specific objectives of the study are the following: 1. Incorporate appointment, reports, profiling, and payment modules in the telemedicine system; 2. Develop chats and videoconferencing feature as an online communication medium that will connect the mentally challenged individuals to professional psychotherapists; 3. Build an online repository of audio psychotherapy tools as an intervention service of the telemedicine system; 4. Apply sensory substitutions through vibrations from amplified audio and audio visualization for the deaf individuals; and, 5. Evaluate the security posture of the telemedicine system using the ImmuniWeb App Security Test.

B. Scope and Delimitation of the Study

In this study, several features were included, namely: the psychotherapists or psychiatrists and their patients could communicate using the chat and videoconferencing feature of the application for the consultation, Digital assessment such as the Kessler 10 (K10) Questionnaire [17] can also be used for additional information about the patient's mental health status. Music psychotherapy and binaural beats are used as audio psychotherapy tools for psychotherapy interventions. The patients can access these music and binaural therapies, and their psychotherapists or psychiatrists gave some.

The use of music psychotherapy and binaural beats for deaf individuals is applied to amplify the volume and bass lines of the audios and visualize music on their mobile screens. The volume and bass amplification were done by having a pre-edited audio file amplified already in the telemedicine system. It is advisable to use a loudspeaker or hold a balloon to enhance deaf patient consultation and therapy experience [18]. The audio visualization display adapted from Tide mobile application plays suitable synchronized music or audio file.

The telemedicine system is designed to focus on the patient's mental health assessment status by using the Kessler 10 Questionnaire. The developed system allows the therapists to use an input question function to customize question and answer activity during therapy sessions. The developed system was designed to cater to all able patients, hard of hearing and deaf patients in the Android mobile environment. Android platform has 85% users, and this percentage is statistically expected to increase up to 86.2% in the next four years [19]. The process flow of the developed system is shown in Fig. 1. The vulnerability and security testing of the system was done to substantiate the system security posture. Resolving all the future vulnerabilities and security issues that were scanned is not a part of this study but is open for future developers to improve the system.

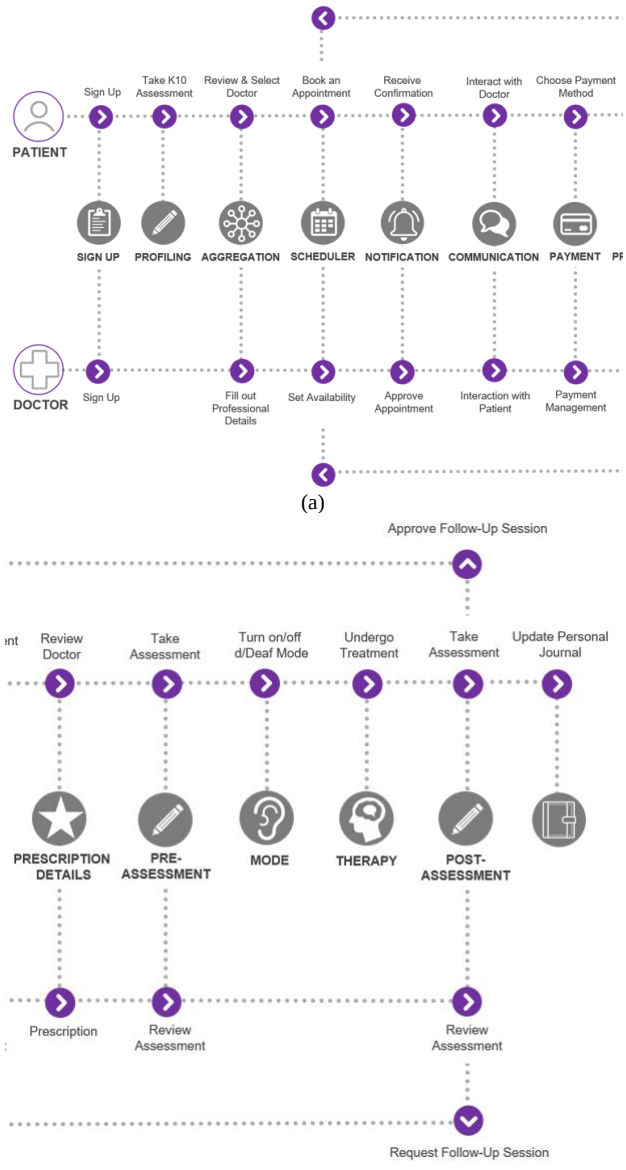

Figure 1. The process flow of the developed system.

II. Review of Related Literatures

In the study of Baharum *et al.* [20], they developed a mobile application that aims to reduce stress and improve moods, including selecting mood playlists, selecting

genres, music selection, and creating personalized playlists for each user. They utilized the Mobile-D method Mobile-D method, which is consists of five phases. First - identification of the features of the application for the application, Second - complete identification of the music and mood category from the conducted quantitative analysis among university students, Third – prototype, and Fourth - phases consists of producing a working prototype of the application and establish the user interface along with the related system. The final phase includes the evaluation of the prototype, the evaluator's feedback was considered and collected for the further modification of the prototype. Their system was evaluated through usability and acceptance testing with product perceptions, user's emotions, and consequences of use. The application received a satisfactory score of 8.2 out of 10.0 that signifies that target users were satisfied with the DeMuse mobile application.

The study of Petry *et al.* [21] is to develop a music sensory substitution system that would provide real-time feedback from different audio input sources that allow for a wearable device for ad-hoc sound access called MuSS-Bits. The prototype design of MuSS-Bits utilized different actuators to implement vibrotactile feedback with ERM motors because of its light-weighted and responsive quality that is vital to achieving real-time feedback with high amplitude. They improved the second prototype by a design split or the sensing from the feedback part (Sensor-Bit and Display Bit) to implement a wireless approach to avoid obstruction due to the cables attached. The latest prototype design replaced the Wi-Fi technology with a Bluetooth module to reduce power consumption and ease of connection with portable devices such as mobile phones. It improved the form factor of the MuSS-Bit by reducing its size close to a smartwatch. A similar study was conducted by Enriquez *et al.* (SENSE: Sensory Component VR Application for Hearing Impaired People to Enhance the Music Experience). Both the former and the latter integrated the sensory substitution in a telemedicine system by establishing an online repository of audio psychotherapy tools that patient users accessed.

The study conducted by Tan *et al.* [3] aimed to compare the effectiveness of integrating Telemental Health (TMH) interventions and conventional face-to-face psychotherapy in improving the quality of clinical and non-clinical outcomes for patients diagnosed with depressive disorder. The study results revealed that TMH interventions are moderately better than face-to-face psychotherapy in treating depression and QOL. However, evidence of its long-term maintenance of effect is inconclusive.

III. Methodology

A. System Design

The developed system has different features given as follows:

Sign-up - The patient users and professional users are both required to register in the application to access the respective features of the system. There are two types of user accounts that have restricted capabilities according to their account type, and each user must register as their respective role in the application. Users are limited to using one e-mail in their registration.

Profiling - The current process requires patient users to complete the K10 assessment before selecting their respective psychiatrists that are proven suited for their profile. It is the patient user's responsibility to honestly answer the assessment for the sake of their diagnostic accuracy.

Aggregation - This process includes the professional users to input their background details that the system will verify. The professional users are required to present proof that they are registered psychiatrists and can handle deaf patients. The patient users are free to select their choice of psychiatrist that the system suggested based on their profile assessment.

Scheduler - The patient user is limited to booking one appointment per day and can have a maximum of one consultation session per day. The patient users must cancel an appointment a week before the scheduled date and time for canceling bookings and cannot cancel an appointment two days before. The patient user also cannot schedule an appointment when they have an upcoming appointment.

Notification - The psychiatrists can choose not to accept a patient request if there is a schedule conflict. The patient and professional users should only select an appointment that fits their schedule to avoid conflict and attend their scheduled appointment only.

Communication - The interaction between patient and psychiatrist will be conducted via video conferencing, and deaf patients are limited to using real-time chat messaging. The maximum number of photos the users can send is set to five (5) photos only. A minor deaf patient user should be assisted by a parent or guardian and must interact with their psychiatrist via videoconferencing means. The screen where the patient users will turn on/off the deaf mode switch is shown in Fig. 2 and Fig. 3. The switch is displayed on the screen after selecting Audio Playlist from the patient's home screen. For the patient to gain access to the audio playlist, the user must select either to turn on or off deaf mode.

Payment - The payment transaction in the process will only occur after the completion of the therapy session. The psychiatrist will set a price for their conducted session. The patient must settle the amount through the payment portal that supports Visa, Mastercard, American Express, UnionPay, and JCB.

Prescription Details - After their therapy session, the psychiatrist can include the binaural beats to the patient in the prescription. The psychiatrist can only prescribe one playlist per session. Deaf patient users are required to activate deaf mode to better experience the binaural beats.

Assessments - The psychiatrist will request the patient fill out a pre-test and post-test to assess the patient's mental status before and after the session. If the

psychiatrist requests the patient users for a follow-up session, the patient-user must book another appointment for the follow-up session for the psychiatrist to produce a diagnosis properly.

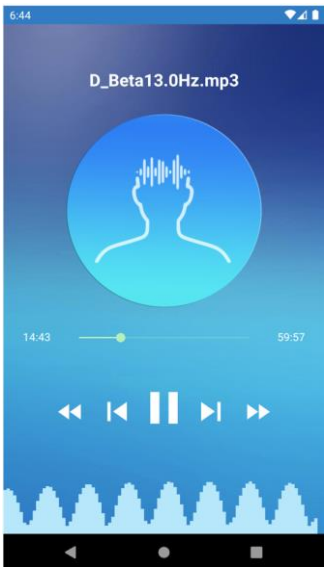

Figure 2. Screenshot of the audio player for the deaf.

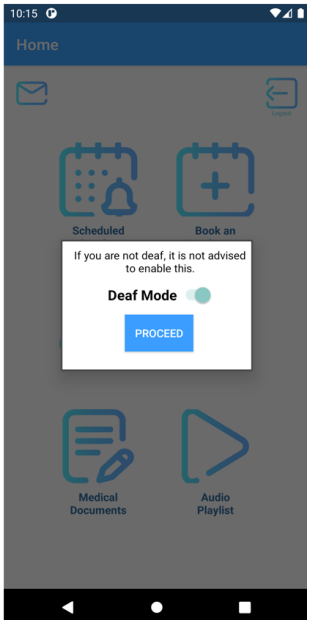

Figure 3. Deaf mode switch screen.

B. System Evaluation

This study used a five-point Likert-type scale to record the level of agreement or disagreement in a particular statement in surveying [22]. The results in this study refer to the different questionnaires answered by the respondents for functionality testing. Other testing included are compatibility, usability, and security posture assessment.

Functionality testing, unit testing, and integration testing followed test cases to validate the system's accuracy and completeness in performing its intended functions [23]. The outline of the test cases was generated based on the process flow, including the subprocesses under the main functions. The compatibility testing showed which version of Android and API Level will run the application. As described, compatibility can be determined if it can run apps correctly and verify that Android is designed to run on different devices such as phones, tablets, and televisions [24]. However, this testing was limited to different mobile devices only. Firebase TestLab was used initially to test it with virtual Android devices. Robo testing is used because it can analyze the structure of the app user interface and explores the functionality automatically [25].

The usability testing was based on the Nielsen Usability questionnaire in assessing mobile health apps because its attributes are considered appropriate for assessing software products. The questions include criteria of efficiency, satisfaction, learnability, memorability, and errors [26]. The formulated questions of the usability questionnaire would be structured per criteria which have the following questions to be answered:

Learnability - Questions under the learnability attribute aim to measure how well users could execute simple tasks in the telemedicine system. It refers to questions that answer "How easy was it for users to learn a task for this feature?".

Efficiency - Questions under the efficiency attribute aim to measure how quickly a user can perform a given task and how many clicks it took to accomplish a task in the telemedicine system. It refers to questions that answer "How quickly are the tasks executed and how many clicks did it take?"

Memorability - Questions under the memorability attribute aims to measure how fast the user can reestablish proficiency in navigating the telemedicine system after a while of not using it by referring to questions that answer "How well are the steps recalled by the user in using the telemedicine system after a long period?"

Error - Questions under the error attribute aims to measure the number of mistakes committed by the user, the degree of the error, and how easy they were able to recover from the error. It refers to questions that answer, "What errors are made by the users, and how many are there?"

User Satisfaction - Questions under the satisfaction attribute aims to measure the degree of satisfaction in using the telemedicine system by referring to questions that answer "How functional is the telemedicine system upon use?".

The questions given for usability testing are structured based on Nielsen's model of usability [27]. The developed system was objectively evaluated using the five usability constituents [28]. The questionnaire is divided into sections based on the specific features identified in the system design, which are appointment, mood journal and report, profiling, payment, chats, videoconference consultation, audio psychotherapy services, and errors. An additional questionnaire was administered for deaf respondents for sensory substitution features ad treated with each question using the Likert scale.

The security posture of the telemedicine system was assessed using the ImmuniWeb App Security Testing [29].

C. Research Design

This study applied quantitative research by conducting a cross-sectional survey from several sample groups to evaluate the developed application using the convenience sampling method [30], [31].

The respondents of this study are the patients (deaf and non-deaf) and certified professionals in the field of psychotherapy who are knowledgeable in music and binaural beats as a method for psychotherapy. Additional twenty-two (22) respondents participated in the functionality testing, which sums up to thirty (30) respondents. The test case passing rate indicates how successful did the respondents were able to execute the test procedures was computed using the formula:

Test Case Pass Rate = (Number of Passed Test)/(Total Number of Tests) × 100, where the Test Case Pass Rate equals the quotient of the number of passed tests and the total number of tests.

For the security posture test, the system's vulnerabilities and security tasks were identified with the ImmuniWeb AI tool. This identified the total number of scanned security risks in terms of the OWASP Top 10 Security Test, Mobile App Privacy and Behavior, and Mobile App External Communications.

IV. Results and Discussion

A. Functionality Testing Result

The developed telemedicine system was subject to testing by three different users, namely the Professional or Doctor user, Non-Deaf, and Deaf users. The test cases were first identified through requirements gathering for each of the telemedicine system's functionality. The test cases were then categorized into three types of functionality questionnaires to test the different functions according to the respondents' needs. The questionnaire listed down each functionality where the respondents evaluated if each functionality is functional by giving it a Passed or Failed. The results of the functionality pre-testing failed the notifications functionality. Nevertheless, post-testing results, as shown in Table I, already fixed the error. Therefore, functional requirements set in the study were met for all target users.

TABLE I. Results of the Functionality Post-Testing

Function Specification	Professional	Patient	Remarks
Sign Up	100%	100%	Passed
Aggregation	100%	100%	Passed
Profiling	100%	100%	Passed
Rating and Review	100%	100%	Passed
Scheduling	100%	100%	Passed
Notification	100%	100%	Passed
Communication	100%	100%	Passed
Payment	100%	100%	Passed
Prescription	100%	100%	Passed
Assessments	100%	100%	Passed
Audio Psychotherapy	100%	100%	Passed
Journaling	100%	100%	Passed

Firebase Test Lab is a cloud-based app testing infrastructure that allows testers to run tests to identify the compatibility of an app on a wide range of Android devices. The results of the compatibility test are shown in Table II. The API levels 24 and 26 to 30 have passed the compatibility test. The telemedicine system is expected to behave on other devices with the same API levels or Android version, which passed the test. However, the outcome of the tests for API levels 23 and 25 has resulted in 'Failed'. The devices that failed the compatibility test were the LG K7 and Sony Xperia KZ Premium.

TABLE II. Compatibility Testing Result in Android Devices

API Level	Android Version	Device Name	Result
23	Android 6 (Marshmallow)	LG K7 (X230)	FAILED
24	Android 7.0 (Nougat)	Huawei Mate 9	PASSED
25	Android 7.1 (Nougat)	Sony Xperia XZ Premium	FAILED
26	Android 8.0.0 (Oreo)	Google Pixel	PASSED
27	Android 8.1.0 (Oreo)	Huawei Honor Play	PASSED
28	Android 9 (Pie)	Google Pixel 3	PASSED
29	Android 10	Google Pixel 4	PASSED
30	Android 11	Google Pixel 5e	PASSED
23	Android 6 (Marshmallow)	LG K7 (X230)	FAILED
24	Android 7.0 (Nougat)	Huawei Mate 9	PASSED

The results on events of instance termination from the FireBase Testlab shown that the app crashed during the test on the device with an API level of 23 which to 'Failed,' remark is due to Java Runtime System error which tries to load a library that is not available with these versions of Android. Since Firebase TestLab is still a beta feature from Google, manual compatibility testing is also done using actual Android devices and Android emulators of Android Studio to verify the results. The result of the manual compatibility testing is shown in Table III. Green cells represent that a function is fully functional in the column of the API level. Orange cells mean that the function can be viewed but is not functional. For the red cells, it means that the function is not viewable and not functional. The manual compatibility testing resulted in the same error with the registration function of Firebase TestLab. It was also discovered that other functions are viewable but are not functional.

Along with registration, editing patient profiles, setting time availability, booking appointments, and accepting or rejecting bookings were all viewable but not functional in API Level 23 and 25 because of the same error with the registration function. Meanwhile, the functions of entering the video conference rooms, skipping a patient, reporting a therapist, and video conferencing are not functional. This is because of the requirement of the DateTimeFormatter class library as well. This function helps in parsing date Strings which made the nonfunctional activities encounter a fatal error and eventually crash. With the rest of the API levels, all functions are fully functional, with no fatal errors found.

TABLE III. COMPATIBILITY TESTING RESULT IN API LEVELS

Functions	API Level	
	23 and 25	24, 26 to 30
Account Registration		
Account Login		
OTP Phone Verification		
Filling up Professional Details		
Answering mental health assessment		
Viewing patient profile		
Viewing therapist profile		
Editing patient profile		
Editing therapist profile		
Setting Time Availability		
Booking appointments		
Accepting or Rejecting Bookings		
Notifications		
Entering Video Conference Rooms		
Skipping a patient		
Reporting a therapist		
Videoconferencing		
Chats		
Payment Gateway		
Therapist Rating		
Medical Documents (Upload and Download Image and Audio)		
Pre and Post Assessments		
Audio Player (Nondeaf Mode)		
Audio Player (Deaf Mode)		
Answering mental health assessment		

B. *Security Posture Result*

The evaluation of the security posture of the developed mobile application, a mobile app privacy and behavior test was performed on the telemedicine system. ImmuniWeb AI was used for this assessment to perform security testing of the mobile application's APK file. The results shown in Table IV. demonstrate the risks and warnings found upon using the ImmuniWeb AI scan in the system's APK file. One high risk was found in the ImmuniWeb scan, which is the weak hashing algorithms with a CWSSv3 base score of 5.5. The mobile application was found to be using a weak hashing algorithm, which is MD5, and this can lead to vulnerability to collisions and other security weaknesses.

There were three scanned medium risks which are the enabled debug mode with a CWSSv3 base score of 5.9. The debug mode used by the application during the development process is best recommended to be disabled once the application is in production. This mode is said to expose technical information about the mobile application, making it vulnerable to reverse engineering. The second medium risk found is the enabled application backup with a CWSSv3 base score of 5.9. This risk means that the mobile application uses external backup functionality that may store inside sensitive data from the application, which may lead to information disclosure. The last medium risk found in the JS enabled in WebView with a CWSSv3 base score of 4.8. JS is disabled by default, but the mobile application has enabled it. This may lead to various JS-related security issues such as Cross-Site Scripting (XSS) attacks.

There were four scanned low-risks which are hardcoded data with a CWSSv3 base score of 3.3. The mobile application contains debugging or other information that an attacker may extract and use to facilitate further attacks. The second low-level risk found is that the mobile application is vulnerable to information with a CWSSv3 base score of 3.3 exposure since it contains hardcoded URLs from the staging or preproduction hosts or APIs. The third low-level risk found is the missing tap jacking protection with a CWSSv3 base score of 3.3. The mobile application does not have a tap jacking protection required to mitigate tap jacking attacks.

Six warnings were also discovered from the scan, first is that the mobile application creates temporary files. Cache files are usually private by default. However, it is recommended to ensure that temporary files are securely deleted when they are not needed by the application anymore. The second is that the mobile application utilizes implicit intent that may be insecure in some instances. It is also discovered that the mobile application uses an intent filter that even not that much of a high risk still poses a severe security risk if not correctly implemented and filtered. The mobile application also uses a dynamic load of executable code, which poses a security threat that can lead to code injection vulnerability if the external storage is readable and writable, giving the attacker access to it. Object deserialization was also found in the mobile application, which can be dangerous if performed on an untrusted resource wherein an attacker can tamper with the data. Lastly, it was also discovered that the mobile application lacks Network Security Configuration in defining which Certificates and Certificate Authorities can be used for various environments.

TABLE IV. IMMUNIWEB SECURITY SCAN RESULTS

Category	Scanned Risks	CWE Category	CWSSv3 Base Score
High Risk	Weak hashing algorithms	[M5] [CWE-916]	5.5
Medium Risk	Enabled Debug Mode	[M2] [CWE-921]	5.9
	Enabled Application Backup	[M2] [CWE-921]	5.9
	JS Enabled in WebView	[M10] [CWE-749]	4.8
High Risk	Hardcoded Data	[M2] [CWE-200]	3.3
	Information Exposure	[M2] [CWE-200]	3.3
	Missing Tap jacking Protection	[M1] [CWE-451]	3.3
	Exported Activities	[M1] [CWE-926]	3.6
Warning	Temporary File Creation	[SAST]	-
	Usage of Implicit Intent	[M1] [CWE-927]	-
	Usage of Intent Filter	[M1] [CWE-927]	-
	Dynamic Load of Code	[M7] [CWE-94]	-
	Object Deserialization Found	[M7] [CWE-502]	-
	Network Security Configuration is not present.	[SAST]	-

For the mobile external communications analysis, ImmuniWeb was able to statically scan the APK file for

the remote hosts that it used, as shown in Table V. These remote hosts are the possible ways to send and receive data. The results of the mobile external communications are shown in Table V. The SSL Encryption Grade is based on whether the hosts follow or support the current TLS protocol. The remote host with the lowest SSL Encryption Grade was Dropbox.

TABLE V. MOBILE EXTERNAL COMMUNICATION SCAN RESULTS

Remote Hosts	SSL Encryption Grade
PayPal Objects	A+
PayPal Stats	A+
PayPal	A+
Braintree Gateway	A+
Braintree Sandbox	A+
Jitsi	A
Braintree Assets Staging	A+
PayPal API	A+
PayPal Sandbox	A+
Dropbox	B+
Stripe Payment	A+
Twitter	A+
Stripe API	A+
PayPal Checkout	A+

According to ImmuniWeb records of tests and scans, the grade of B is due to the non-compliance with NIST by using TLS 1.0 only. This is also not compliant with the SP 800-52 REV. 2 and PCI DSS [32]. Overall, the SSL Encryption Grade results are good to excellent and considered to be compliant with security regulations as most remote hosts had a grade of A and A+. This result is considered reasonable compared to the other mobile application scans done in ImmuniWeb.

C. Usability Test Results

There were three usability questionnaires administered to each type of respondent (Professional, Deaf, and Non-Deaf). The usability result of the non-Deaf participants is shown in Table VI. Attributes of usability include the following: E=Efficiency, L=Learnability, M=Memorability, and S=Satisfaction. All the mentioned functions presented in the table had resulted in a mean score of 5.00 under the attribute Efficiency. Therefore, the respondents were able to perform their tasks efficiently. In terms of the attribute Learnability, the functions Appointment, Mood Journaling and Report, Profiling, Payment, and Chats had resulted in a mean score of 5.00. Therefore, the respondents were able to learn the mentioned functions of the system quickly. However, the function Videoconference Consultation has a mean score of 4.67 for Learnability, while Audio Psychotherapy Services has an average score of 4.82. The scores of the last two mentioned functionalities are still considered acceptable for the respondents in terms of Learnability. Appointment, Profiling, Payment, Chats, Videoconference Consultation, and Audio Psychotherapy Services had a mean score of 5.00 under the attribute Memorability. The function Mood Journaling and Report had an average score of 4.82 under Memorability. This means that the functions are easy to remember. In terms of Satisfaction, the functions Appointment, Mood Journaling and Report, Profiling, and Audio Psychotherapy Services had an average score of 5.00. For the rest of the functions, Payment, Chats, and Videoconference Consultation, they had a mean score of 4.67. This means that the respondents have a positive attitude towards the functions of the system. Under the Errors section of the questionnaire, it resulted in a mean score of 4.56. This means that some of the respondents had encountered minor errors from the system, yet still acceptable.

TABLE VI. USABILITY TEST RESULTS FROM NON-DEAF RESPONDENTS

Functions	E	L	M	S
Appointment	5.00	5.00	5.00	5.00
Mood Journaling and Report	5.00	5.00	4.82	5.00
Profiling	5.00	5.00	5.00	5.00
Payment	5.00	5.00	5.00	4.67
Chats	5.00	5.00	5.00	4.67
Videoconference Consultation	5.00	4.67	5.00	4.67
Audio Psychotherapy Services	5.00	4.82	5.00	5.00
Mean Score = 4.56				
Legend: **E**= Efficiency, **L**=Learnability, **M**= Memorability, and **S**=Satisfaction				

The usability result from the respondents who are mental healthcare professionals is shown in Table VII. The functions Payment, Videoconference Consultation, and Audio Psychotherapy Services had resulted in a mean score of 4.50 under the attribute Efficiency. For the functions, Appointment and Profiling had resulted in an average score of 4.00. The mentioned scores mean that the functions are acceptable in terms of Efficiency. The respondents were able to perform tasks with efficient consumption of usability resources. Lastly, under the attribute Efficiency, the functions Mood Journaling and Report and Chats had resulted in a mean score of 3.50. The mentioned scores mean that the functions are neither acceptable nor unacceptable in terms of Efficiency. The respondents were neither able to perform their tasks on time or with delay. For the attribute Learnability, the functions Payment, Chats, Videoconference Consultation, and Audio Psychotherapy Services had resulted in a mean score of 4.50. In comparison, the functions Appointment and Mood Journaling and Report had resulted in an average score of 4.00. These figures mean the functions had allowed the respondents to complete tasks since the system is easy to learn on the first run. Under Learnability, the Profiling function had resulted in a mean score of 3.50. This means that the mentioned functions are neither easy nor hard to learn, according to the respondents. Appointment, Mood Journaling and Report, Payment, Videoconference Consultation, and Audio Psychotherapy Services resulted in a mean score of 4.00 under Memorability. This means that the system's functions, according to the respondents, allows them to remember to some degree how to use the functions even after returning to the system after a period. The function Chats had resulted in an average score of 3.50, while the

function Profiling had resulted in an average score of 3.00 under the Memorability attribute. This indicates that the professionals neither considered the functions under the mentioned attribute easy nor hard to recall after returning to using the app after a period. The functions Payment, Videoconference Consultation, and Audio Psychotherapy Services had resulted in a mean score of 4.50 under Satisfaction. The function Appointment and Chats has resulted in a mean score of 4.00 for the attribute Satisfaction. The functions Mood Journaling and Report and Profiling had resulted in a mean score of 3.00. The mentioned scores mean that the respondents had experienced contentment towards the system's functionalities except for the Report and Profiling, which resulted in a neutral mean score. The functions that had resulted in a neutral mean score means that the respondents are neither satisfied nor unsatisfied with the functions. The attribute Error has a mean score of 3.33. This implies that the respondents had encountered some errors while using the system, which is not fatal to make the system crash.

The usability result from the Deaf individual's answers from the usability questionnaire is shown in Table VIII. The number of respondents that have answered this questionnaire is 3. The functions Appointment, Mood Journaling and Report, Profiling, Chats, Videoconference Consultation, Audio Psychotherapy Services, and Sensory Substitution under the attribute Efficiency ranges had resulted in a mean score from 4.00 to 4.67. This means that the functionalities allow its users to perform their tasks efficiently. However, the function with a mean score of 3.67, in terms of Efficiency, is the Payment function. This means that the Deaf respondents find the payment function neither efficient nor inefficient. The mean scores of the functions Appointment, Profiling, Chats, Audio Psychotherapy Services, and Sensory Substitution under the Learnability attribute ranges from 4.00 to 4.67. This means that the Deaf individuals were able to understand the system's functionalities quickly. The functions Mood Journaling and Report, Payment, and Videoconference Consultation had resulted in a mean score that ranges from 3.33 to 3.67. According to the respondents, this means that it is neither easy nor hard to learn the mentioned functions. The function Chats had a mean score of 4.67 under the attribute Memorability. Under Memorability, the functions Appointment and Audio Psychotherapy Services had a mean score of 4.34. The functions Mood Journaling and Report, Payment, Videoconference Consultation, and Sensory Substitution had a mean score of 4.00 under the Memorability attribute. The mentioned scores mean that the functionalities allow the respondents to recall its functions after returning to using the app after a period. Under the attribute Memorability, the function Profiling had a mean score of 3.67. This means that the functions under Profiling are neither easy nor hard to recall after returning to using the app after a period. Lastly, the mean score of the functions Appointment, Mood Journaling and Report, Payment, Chats, Videoconference Consultation, and Audio Psychotherapy Services under Satisfaction ranges from 4.00 to 4.67. The mentioned range means that the Deaf individuals lean to the positive contentment towards the system's functionalities. Satisfaction towards Profiling and Sensory Substitution function has resulted in a mean score of 3.67, which means that this function neither provides satisfactory or unsatisfactory to the Deaf users. The attribute Error-free has resulted in a mean score of 3.67. This means that the respondents had encountered some errors within the system and is neither acceptable nor unacceptable.

TABLE VII. USABILITY TEST RESULTS FROM MENTAL HEALTHCARE PROFESSIONALS

Functions	**E**	**L**	**M**	**S**
Appointment	4.00	4.00	4.00	4.00
Mood Journaling and Report	3.50	4.00	4.00	3.00
Profiling	4.00	3.50	3.00	3.00
Payment	4.50	4.50	4.00	4.50
Chats	3.50	4.50	3.50	4.00
Videoconference Consultation	4.50	4.50	4.00	4.50
Audio Psychotherapy Services	4.50	4.50	4.00	4.50
Mean Score = 3.33				
Legend: **E**= Efficiency, **L**=Learnability, **M**= Memorability, and **S**=Satisfaction				

TABLE VIII. USABILITY TEST RESULTS FROM DEAF RESPONDENTS

Functions	**E**	**L**	**M**	**S**
Appointment	4.00	4.00	4.34	4.67
Mood Journaling and Report	4.33	3.67	4.00	4.33
Profiling	4.67	4.33	3.67	3.67
Payment	3.67	3.67	4.00	4.00
Chats	4.33	4.67	4.67	4.67
Videoconference Consultation	4.00	3.33	4.00	4.33
Audio Psychotherapy Services	4.00	4.17	4.34	4.34
Mean Score = 3.67				
Legend: **E**= Efficiency, **L**=Learnability, **M**= Memorability, and **S**=Satisfaction				

V. CONCLUSION

This study developed a psychotherapy telemedicine system utilizing a sensory substitution feature for audio-based interventions that enabled deaf users to experience the said interventions. The developed telemedicine system includes appointment booking, report viewing, profiling, and payment modules in a mental health telemedicine system with a functionality pass rate of 100% and an overall usability score of 4.35, 4.14, 4.09, and 4.27. The telemedicine system was also able to include video conferencing and chat features to provide a convenient communication medium that would connect the mentally challenged individuals with their professional psychotherapists or mental healthcare professionals. This function also attained a functionality result with an overall usability score of 4.28 and 4.36, respectively. Also, the system was able to provide an online repository of audio psychotherapy tools as an

intervention service of the telemedicine system. The system offers a deaf mode for the deaf community that enables them to experience the binaural beats with audio visualization and the amplified bass of the songs with an overall usability score of 4.18 and a 100% passing rate in the functionality testing. All of these mentioned features had good usability results in Nielsen's usability model from the perspective of mental health professionals and patients, both deaf and non-deaf users. The security posture of the developed telemedicine system is considered acceptable, based on ImmuniWeb standards, despite having a weak hashing algorithm used.

The integration of audio interventions in a telemedicine system provided an efficient way of giving psychotherapy services for mental health. This feature can also be quickly learned and reused by mental health patients, which gives them the satisfaction of gaining mental healthcare in remote psychotherapy. The overall usability rating score for this function in terms of efficiency, learnability, memorability, few errors, and satisfaction, is 4.18 which is a good indicator of positive usability impact to the deaf and non-deaf users. The professional mental healthcare professionals or psychotherapists who used the system were all satisfied with the audio interventions integrated into the system. They were also able to use it with ease and recall this functionality without problems. Therefore, the integration of audio intervention tools, such as the alpha and beta binaural beats, can allow possible patient users to access audio psychotherapy tools with ease and satisfaction. At the same time, the psychotherapists can use these audio interventions as a mode of treatment for their possible patients when using the developed telemedicine platform.

This study suggests the following improvements for future researches in the related telemedicine field: 1). have a psychoanalysis approach for the mental health effects of the audio psychotherapy tools in a telemedicine system; 2). add a third-party tool to integrate sign language in a videoconference for better communication between a deaf patient and the doctor; 3). enhance the audio-visualization for a better experience with the binaural beats for deaf patients with advanced graphic visualizations; 4). address other Android versions and develop to other mobile platforms; and, 5). use a more robust hashing algorithm than MD5 to improve the mobile application's data encryption.

CONFLICT OF INTEREST

This research paper presentation and registration was funded by Mapua University. All authors declare that they have no conflicts of interest.

AUTHOR CONTRIBUTIONS

Ms. Samonte supervised the whole research development and took the lead in writing the manuscript. Mr. Marin worked out almost all of the technical details. Ms. Anson and Ms. Encinas contributed to the design and implementation of the research, to the analysis of the results and to the writing of the manuscript. All authors discussed the results and commented on the manuscript.

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