Bubbles*: A Mobile Application Aimed to Alleviate the Spread of COVID-19*

A Major Qualifying Project submitted to the Faculty of

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Abstract

Digital contact tracing applications instill public fear as they store large amounts of user information. Problems often arise as users are unsure of how their data is stored. Due to this, people are less likely to download these COVID-19 tracking applications and they become non-reliable for contact tracing. This report outlines our solution to this problem: an application that is not “scary” and intimidating for the public to use. In this project, not “scary” is defined as collecting as little user data as possible, transferring data using best encryption practices, not visually overwhelming to the user, and limiting the potential for bad actors to misuse information. To develop this application, we researched security protocols, user interface best practices, and ways to present data in easy-to-understand terminology. We then compiled this research to create *Bubbles*, our groundbreaking method of sharing self-reported COVID-19 information within close-knit groups, or “bubbles.”

Introduction

Digital and manual contact tracing have emerged as ways to mitigate the COVID-19 pandemic. Digital contact tracing applications use locational awareness, via GPS and low-wave Bluetooth, to easily alert users when they have been exposed to the virus. A common privacy issue within digital contact tracers is the substantial amount of personal data collected. Because of this, users are less inclined to use these applications, and therefore they have not received the required traction to be successful in mitigation (Kreps, Zhang, & McMurry, 2020).

Bubbles presents a solution to this issue by focusing on users' privacy and being transparent about how personal data is stored. Within our application, users establish bubbles with their friends, family, and peers in their day-to-day lives and form circles of interaction. *Bubbles* utilizes this concept to monitor the COVID-19 infection status of a user's interaction group. When users download *Bubbles,* they are given the option to create a new group or bubble. Each user inputs minimal information to create their profiles and can then join a bubble. A bubble acts as a visual way of representing the group, storing close contacts and positive tests. The application allows the user to input their recent COVID-19 tests and save the status to their account. The application then shares the testing status with other members, based on the sharing settings in the group. This is presented in a user-friendly manner, without technical or medical jargon, so that all users can comprehend it. By allowing the users to input data—first name, last name, and most recent testing result—on an opt-in basis, as well as removing the GPS and Bluetooth tracking, the user has more control over their information and privacy. *Bubbles* provides the user with clear information about how their data is stored and protected, along with who can access their data.

The backend goal of our application was focused on protecting and storing user data. To increase a user's privacy, minimal user information is stored. As information is updated, the secure Firebase server will notify contacts in the form of end-to-end encrypted data messages. All other user information, such as the private key used during encryption, is stored locally on their device.

The driving goal of our Major Qualifying Project was to understand why users view digital contract tracing applications as scary or daunting to use and how to address this discrepancy. As referenced in the journal article "Digital Contact Tracing for COVID-19" from the CMAJ, combining both forms of contract tracing is an effective way to protect yourself and others from COVID-19 (Merkel and Kleinman, 2020).

The corresponding project report includes the following sections: background, design and implementation, evaluation methodology, results and discussion, and conclusion. Background explores specific ethical and privacy issues that exist for both manual and digital contact tracing, along with industry mobile application design practices which allows us to fully understand the scope of the problem. Design and Implementation outlines the application creation process and the technical information used when creating the application. We then outlined the process for testing the application within the Evaluation Methodology, including how we collected interview feedback. Our analysis of interviews was examined in both the Evaluations and Discussions and the Results section. The Conclusions section explores all of our project's data.

Background

Given the importance of quick action against the COVID-19 pandemic, the need for tracing the contacts of infected individuals has proven to be crucial. To aid in this, public health officials and organizations, such as the Center for Disease Control and Prevention (CDC), turned to contact tracing as an essential way of controlling the spread of potential infections while vaccines are being developed and distributed. To stop the spread of the COVID-19, it was fundamentally important to perform contact tracing as effectively as possible by making use of electronic means, such as contact tracing applications. In addition to producing results efficiently, contact tracing applications need to inspire confidence and trustworthiness.

2.1 Traditional Contact Tracing

Traditionally, manual contact tracing involves a trained team conducting interviews with those who have been infected. Using information from these interviews, this team learns who the infected individual recently encountered. The contact tracers will then inform those deemed “close contacts” of their exposure, ask them to quarantine, and explain the necessary steps to follow, such as testing protocol. Close contacts are defined as those who are nearby within 6 feet for 15 minutes or more. Furthermore, contact tracers can refer necessary services and resources to those diagnosed with COVID-19. This form of contact tracing offers a sense of support and understanding. Manual contact tracing is incredibly labor-intensive, as the interviewing process and informing individuals of their potential infection can be lengthy. Manual contact tracing also depends on the memory of the infected individual and their ability to recall information about those that may have been exposed.

2.2 Digital Contact Tracing

Recently, mobile phones and other digital information technology have greatly improved the contact tracing process by tracking contacts of potentially infected users. The main forms of this tracking technology are GPS, which uses satellites to find the location of a person's phone within a limited range, and low-energy Bluetooth, which can detect a person's location within 30-40 feet. A downfall to these methods is their inability to account for individuals following social distancing and masking guidelines. This results in high chances of false-positive contact notifications, potentially scaring the user.

Privacy advocates have raised concerns that data is not stored anonymously, causing abuses of civil rights. This is a core reason digital contact tracing has not been widely accepted in the United States. In a survey, 49% of people who said they would not use digital contact-tracing applications cited privacy concerns as being the main reason (Sowmiya, B. Et Al., 2021). From these survey results, one can determine it is important for a user to feel confident their information is being stored securely. If a user has any doubt that the application is not safe, they will be less likely to use the application.

2.2.1 Application Standards

When designing applications, a user's needs must be kept in mind. It is critical to a user's wellbeing that all personally identifiable information (PII), or data that can identify a user, is encrypted. Some examples of this information include social security numbers or home addresses. In addition to this PII, many applications available store test results, exposures, symptoms, and vaccination records. According to the WHO, all application data must be erased as soon as contact tracing is no longer needed to achieve public health objectives and should only

be stored as long as it is needed (WHO, 2020). This standard will keep the user safe and less scared their data can be used for malicious purposes.

With the user's safety in mind, applications should only request information voluntarily and provide the user ability to quit entering data at any time. Not forcing the user to enter specific information will increase comfort. Regardless of the precautions taken to keep a user's PII safe, it must be explained to the user how the application stores and manages data. Users will be more willing to use and trust an application if they are aware of precautions to keep their data safe, and will therefore find the application less intimidating to use (Bengio, Y. Et Al., 2020). Furthermore, users should be provided with reader-friendly information regarding the purpose of collection, types of data collected, how data will be stored and shared, and how long data will be retained.

2.2.2 Current Digital Contact Tracing Applications

Some applications currently available include COVID Watch AZ and COVID Alert PA. COVID Watch AZ allows users to enter COVID-19 test results and choose if this information is stored in the application. On the other hand, COVID Alert PA requires health officials to enter test results but allows users to decide if the information is shared with others (COVID Alert PA App, COVID Watch AZ Exposure Notifications). We have also found that some applications are prompt to inform users that they will not be storing personal information and not track users' location on their website. This is often achieved through notifications upon a user opening the application. Users are provided with the option to learn more on the application's website and additional detail about the application's code for those interested (COVID Watch AZ Exposure Notifications, COVID Alert PA App). Apple and Google's API Exposure Notification requires

users to opt-in before use, they are also given the option to opt in or out from alerts notifying them of close contacts (Google, 2021).

2.2.3 Ineffectiveness of Digital Contact Tracing

Through our research, we have found that current applications are ineffective at tracking those with COVID-19 due to low adoption rates. “To stop the spread of the virus, at least 60% of the population must download [and turn on] the app ” (Kaya, E. K., 2020). To create an effective application that slows the spread of COVID, programmers must take into consideration the population as a whole and not disproportionately target certain groups. For example, developers must account for both older adults as well as minors (WHO, 2020). Older adults need an application that is easy to understand and use. Minors, on the other hand, might need parental permission or controls depending on what data is being collected from them.

2.3 Motivation

Considering both forms of contact tracing and their pitfalls, our team decided to create an application that allows users to manually report their COVID-19 test data, balancing both users’ privacy and reporting speed. From our research, we have found that the most influential way to stop the spread of COVID-19 is to combine both manual and digital contact tracing. A study conducted in 2021 claimed that if manual and digital contact tracing worked in tandem, there would be about an 80% decrease in epidemic size (Barrat et al., 2020).

Currently available applications aim to inform a user’s contacts and strangers of possible infection based on proximity. These digital contact tracing applications do not take into consideration if social distancing and COVID safety guidelines are followed. This can lead to

incorrectly notifying people resulting in stress and fear. *Bubbles*, on the other hand, allows users to manually report COVID-19 infection, notifying those they interact with most. It also allows the user to self-label themself as a close contact.

In terms of efficiency, a critical goal of this application is to decrease the time between contact tracing and exposure notification. For our application to be successful, it will inform users of potential infection faster than manual contact tracing. This is accomplished through one message going to multiple groups at once (bubbles). To make the concept more concrete, mass communication could be compared to a mass email: in one click a user notifies a whole bubble, or multiple bubbles, of their infection. When compared to manual operations such as interviews and phone calls, digital contact tracing is easier to understand and faster.

Current manual contact tracing involves the infected individual recalling each of their contacts during an interview with a manual contact tracing team. The team will then speak to each of those mentioned as close contacts to notify them of their potential infection. The use of *Bubbles* decreases this time since as soon as the user is told of their infection they will quickly spread the information to their close contacts.

2.4 The Importance of Design Principles

When considering application features that scare users, one must examine both user interaction and interface (UI). Applications created following design guidelines standards in the mobile industry are regarded as having a better user experience than applications that stray from these guidelines. Two prominent guidelines for UI Design are the Shneiderman and Plaisant (2009) and the Nielsen and Molich (1990) models. Outlines of these guidelines are seen in the figure that follows.

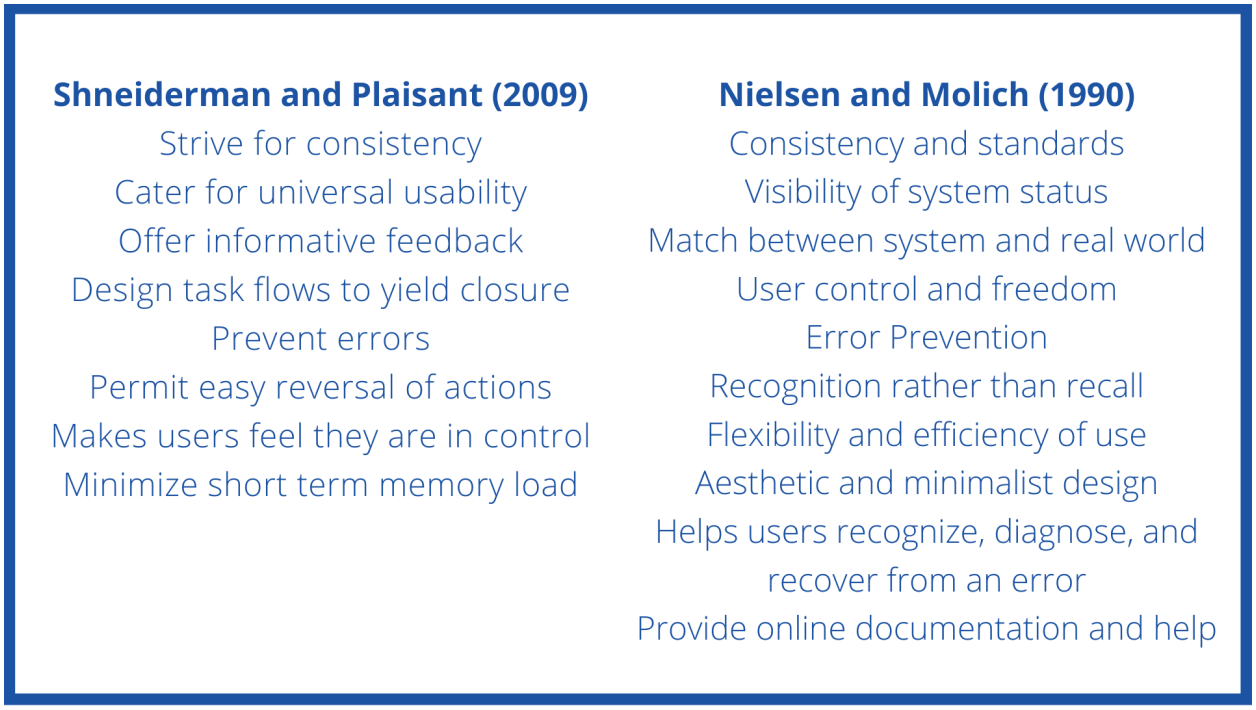

Figure 1: Shneiderman and Plaisant (2009) and Nielsen and Molich (1990) Guidelines for UI Design

These guidelines stem from perceptual psychology (how the brain perceives the world around them both consciously and unconsciously) and cognitive psychology (how the brain processes attention, language use, memory, problem-solving, perception, creativity, and reasoning). By focusing on how the brain functions to create design guidelines, application designers can anticipate users' reactions to the application. Therefore, designs can influence how the user feels consciously and subconsciously.

When designing the structure of our application, we considered Gestalt's principles of visual design (proximity, similarity, continuity, closure, symmetry, figure/ground, and common fate) to drive our application structure. These principles were essential in creating the bubble

concept. We followed this guideline by placing user data within proximity; therefore, the user will feel that the information is connected and will be easier to remember.

Following these design principles was critical to our goal of making the application not intimidating to the potential users. When applications have a consistent design across their platform, users will know what to expect, preventing surprises. Users will, therefore, feel they are in control of their data, and, if so inclined, will choose to share data. According to the aforementioned psychological concepts, by structuring applications correctly, the human brain will naturally group items together. This allows users to process information faster and easier compared to information that was unrelated and presented randomly. By combining these design principles, we hope to create an application that the user will feel comfortable using and sharing information.

Design and Implementation

In this section, we highlight the application design process, such as design goals, as well as implementation methods for the front-end, back-end, and server-side development. We review the process for prototype testing, encryption techniques, and design selections for the application and library choices.

3.1 Design Goals

The main design goal was for a user to not be scared of the application. To accomplish this, the main task is the transparency of data storage. The biggest pitfall of other digital contact tracing applications is that users do not feel safe; therefore, they will not use them. This makes the application less reliable and effective. To reduce "scariness," *Bubbles* clearly explains how information is stored, asks for minimal user data, and ensures only a user can access their information. If a user understands this information about their data and the developer's willingness to disclose this information, the user will be more likely to trust the application.

When communicating how information is stored, we wanted to preserve the user's ability to decide who can see their COVID-19 status. To do this, *Bubbles* offers both "hidden" and "visible" bubbles. A "hidden" bubble does not share any individual COVID-19 status information. This bubble type will notify a user that someone is positive or in close contact, but will not display the individual. Hidden bubbles display less information about the infected user. If a user in a hidden bubble enters a positive test, others within the bubble will receive a notification stating there is an infected user in the bubble, but will not display information about the user. On the other hand, a visible bubble will identify the individual who is a close contact or

tested positive. If a user in a visible bubble tests positive, individuals in the corresponding bubble are told the name and status of the infected user via a red border around their avatar. When a person in a visible bubble is negative their avatar will have a green border and if they are a close contact, yellow.

To minimize collected information, a user will self-report data, such as positive COVID-19 tests, to the application. Specifically, we use self-reported data so location data is unneeded. This information will then be sent, based on user-defined settings, to their bubbles. The users within the bubble will then receive the total close contacts in the group and the number of positive tests on their dashboard screen.

End-to-end encryption is a form of protected transfer of data where only the users communicating will be able to access the information. Both encryption and decryption occur on the device to eliminate other parties, such as hackers or large corporations, from accessing the data.

3.2 Functional Requirements

The application has to support several main functionality features to accomplish its purpose, which we outline below and will further explain later within this section. This includes the following:

I. Adding a user
II. Adding a COVID-19 Test
    A. Encrypt testing status
III. Creating a new visible bubble
IV. Creating a new hidden bubble
V. Join an existing bubble
VI. Load a user's list of bubbles
    A. Display user's bubble names
    B. Display the bubble's privacy settings
    C. Display the total close contacts and positive test results
VII. Load current bubble members in each user's bubbles
    A. Decrypt testing status
        1. Display color border corresponding to COVID-19 status
    B. Display the user name

3.3 System Architecture

Our system consists of three primary components: the front-end user application, the back-end of the application, and the data storage system. The front-end application displays and renders information from the storage system to the user and controls the user interactions including button presses and keyboard input. The back-end processes the front-end updates and carries out the routing of the applications and calls any system logic calls including updating the data storage and controlling internal variables and encryption/decryption of data. Finally, the back-end system then updates the device storage and pushes and fetches new data from the local device storage or the NoSQL database. The figure below provides a visual of this system architecture.

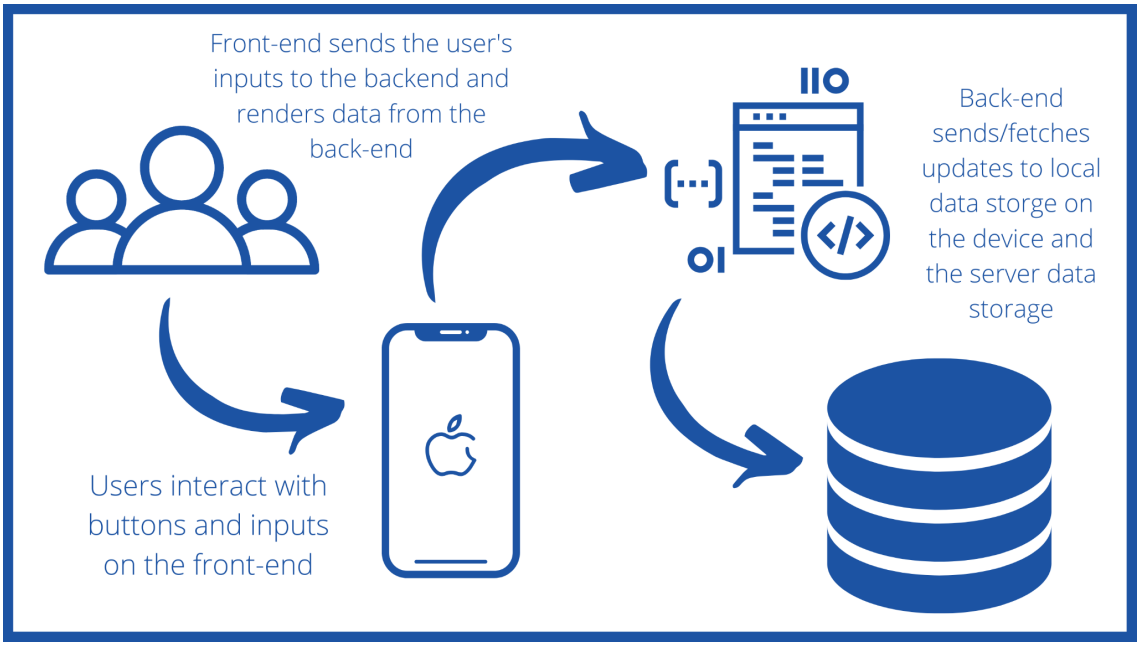

Figure 2: System Architecture Diagram

3.4 Front-End

The front-end is a smartphone application that consists of the user interface including image views, buttons, and view changes. To make a graphic interface easy to use we followed the design principles and followed commonplace for application design. For our color palette, we used contrasting colors that were run through the Adobe Color Contrast Analyzer. This tests for various accessibility concerns including visual deficits and various levels of common color blindness. Our color palette passed both the regular and large text contrast checks along with actionable icons, which allows the application to be used comfortably by a wide audience. All buttons, other than arrows, feature labels, which allows devices with accessibility settings enabled to interpret the label via screen readers. The application does not feature rapid movement or animation, which prevents migraines or triggering epileptic episodes in those at

risk (Mozilla, 2022.) All of these support the Web Content Accessibility Guidelines (WCAG) V2.1, which is one of the most popular outlines for accessibility practices in the industry.

A key focus of our front-end design process was to ensure that the application felt intuitive to use for the user compared to the application they already use. Buttons for routing page to page were placed on the right-hand lower corner and icon shapes that were unique for the application, such as the “Add a Test” icon, were labeled so the user would know. We tested the front-end design via prototyping, as outlined in the following sections.

3.4.1 Low Fidelity Prototyping

For the front-end application design, our team sketched mockups of low fidelity prototyping. For each view, the team depicted basic user functionality; to do this, we tested screen flows and ensured necessary components were displayed on the screen. Creating prototypes allowed us to visualize the application layout before coding as well as develop improvements without having to recode the application. In this stage of the application testing, only components such as the “Add a Test” icon and the bottom navigation bar were featured, there was no functionality. We also performed informal testing which provided us with feedback on our initial design. During testing, users clicked between the wireframes of each view. By focusing on core components rather than mock images, the provided feedback was focused on the functionality of the core application.

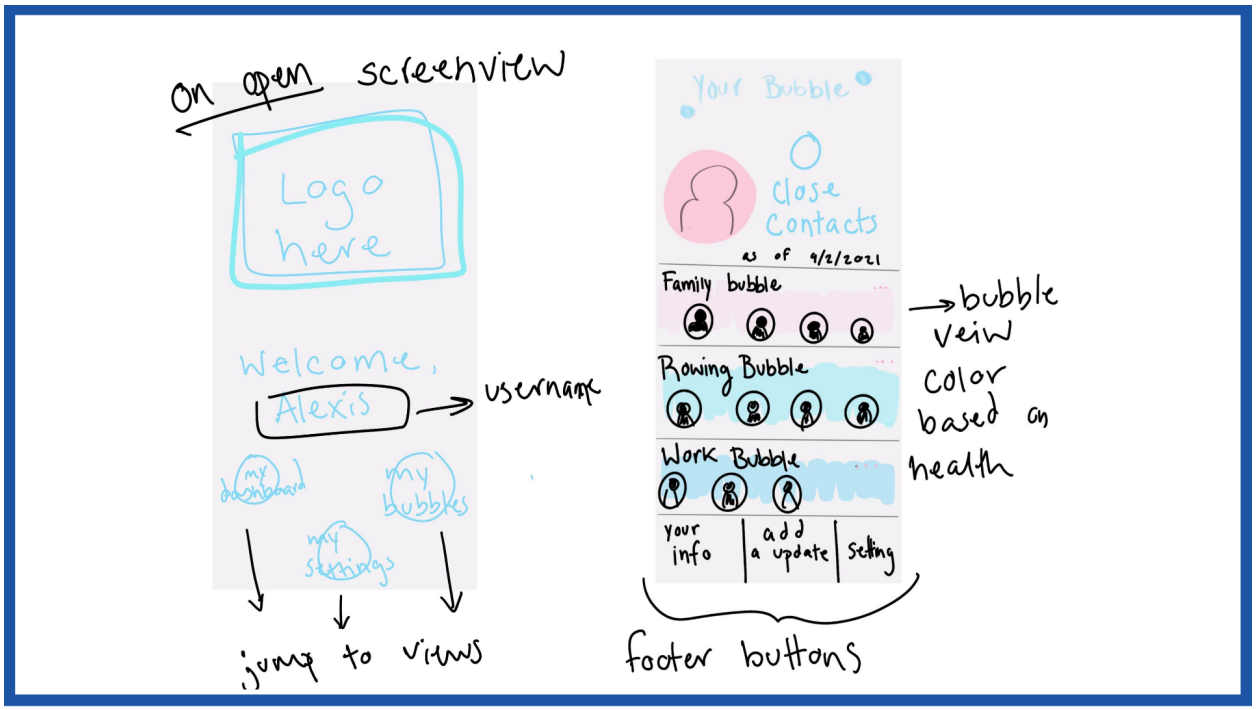

Figure 3: Initial Mockup Examples

3.4.2 High Fidelity Prototyping

The next iteration, the high fidelity prototype, is closest to the application vision. This step allowed us to gain feedback on vector graphics, colors, and layouts in proportion to the rest of the screen. During this phase, we focused heavily on removing white space within the application and highlighting the most common actions for the user. Through informal testing throughout the design process, we determined users wish to accomplish common actions such as adding tests, joining bubbles, or viewing bubble status on the dashboard. Our team also tested the size of the icons and ensured users were easily able to access the most commonly used items.

Figure 4: Initial High Fidelity Adobe XD Designs

3.4.3 Prototype Testing

When testing the application's prototype, our team conducted think-aloud sessions to gain feedback on the design. Think-alouds are a method used to gather data about product usability and design in the early stages of application development. These sessions are useful as participants are encouraged to provide their honest opinion regarding the user interface, application functionality, and any other insight. We asked participants for their reactions and first instincts when viewing each screen, along with any questions they may have. When asking for feedback, the team selected a wide range of people, including those in the 18 to 66 year age group. This diversity allowed us to obtain a variety of opinions on application flow and determine if the application is counterintuitive to users.

3.4 Back End

Security is an important goal when dealing with health information. As we discussed earlier, we store as little user data as possible. Information such as an individual's bubbles, contacts, and COVID-19 testing status is stored locally on their device. We decided a user's information would be safer if stored locally on their device as it is in their possession.

The back-end controls the application's routing, as well as all system logic calls such as data storage and controlling internal variables. The back-end is used to encrypt and decrypt data. The back-end system updates the device storage, it is responsible for pushing and fetching new data from the local device storage or the NoSQL database.

3.5 Implementation

We used the Expo framework to build the React Native application. This section describes the front-end, back-end, and server-side development. As well as the end-to-end encryption protocol which ensures safe transfer of data.

3.5.1 Expo, React, & React Native

The project is written in React Native, a variation of the React language. This framework was chosen due to its ease of use and ability to run on both iOS devices (traditionally requiring Swift as the coding language) and Android (running Koltin.) React Native is closest to JavaScript or TypeScript, which is close to the iOS/Android coding languages of choice. This reduced the workload of the team otherwise two applications in two different languages were required. Our project uses a framework called Expo, chosen because of its rich integration with React-Native. Expo allowed us to pair our own mobile devices to test the application on our phones, which allowed the team real-time debugging of the application.

3.5.2 Front End Development

When working on the implementation of the front-end application the team found several additional libraries to aid in the creation of our project. Our Expo packages included *expo*, *expo-app-loading*, *expo-font*, *expo-constants*, and *expo-status-bar*. Adding these packages allowed us more versatile usage of the Expo development environment. Starting with the navigation stack, we imported *react-naviagtion* packages like *react-navigation/bottom-tabs, react-navigation/native-stack,* and *react-navigation/native.* This allowed us to develop screen navigation within the application. We have the addition of components maintained by users like *react-native-toast-notifications* and *react-native-bouncy-checkbox* which allowed us to create UI components similar to specific devices within our application.

Figure 5: Final Version of Add A Bubble's & Dashboard Front-End Design

3.5.3 Back-End Development

Within the application, there are several actions a user can perform that influence the information on the application side. When a user joins a new bubble, their universally unique identifier (UUID), first name, last name, and an encrypted COVID-19 status will be sent to the server, which is then updated and pushed to all members of the corresponding bubble. This changes the view of the Bubbles page. When a user enters a positive COVID-19 test, their new test status and identification number will be sent to the server, and a request to update the corresponding bubble members' displays. When a user changes their status manually their new status and identification number will be securely communicated to members of each bubble the user participates in. When a user changes their profile name, their new name and identification number are sent to the server and each member of the given bubble will receive an update to their display on the Firestore.

3.5.4 Server-Side Development

Upon opening the application, a user will be assigned a UUID. This randomized number is not connected to any personal information and is the only data necessary to store[1]. This number is used as an address for the server when sending messages. Once a message reaches its recipient(s), the message will be deleted. The data associated with that message will be stored locally on the recipient's device. Therefore, only the user's confirmed contacts have this personal information.

A critical feature of this application is ensuring malicious actors are unable to access private data messages. To achieve this, we created a secure Firebase server and implemented

[1] Because of this if the application is deleted off a device or a user gets a new device, they will not be able to redownload their bubbles, they will have to manually rejoin.

end-to-end encryption, or protocols to secure messages from the sender's phone to the destination. The Firebase server was decided upon due to its usability, efficiency, and developer testing capabilities**.** According to Firebase documentation, all Firebase products encrypt data in transit (Firebase, 2021). Data must be encrypted at rest. To ensure only the intended recipients have access to users' data, we used Virgil Security encryption protocol in tandem with Firebase, which prevents even the developers and anyone working for Virgil or Firebase from accessing user's private data.

3.5.5 End-to-End Encryption

Data is encrypted on the client, the user's device, before sending it to the Firebase server. This ensures the middle infrastructure will never get to see data in its raw form. When the data is sent from the server to the recipient's device it is decrypted. This is done through Virgil Security's public and private key pairs. Upon account creation, a key pair is generated for the user. This pair is stored through the React Native Keychain, which we decided was the best option to store credentials in the React-Native mobile application. We chose this option as it allowed the private key credentials to be securely stored locally on the user's device. Messages are encrypted through the *virgilCrypto.encrypt* function, which requires a message and a public key. Because of the nature of encrypted messages, the encrypted data will also be Base64 encoded. Base64 is a binary-to-text encoding schema that represents binary data in an ASCII string. This encrypted message will be sent to the Firebase database, and will then be sent to the recipient's device. Even if a malicious actor were to obtain access to the database, they will be unable to read the data as it is encrypted with the user's private key which is stored locally on their device. Once sent to the recipient, the encrypted message will be decrypted by the function

virgilCrypto.decrypt, which requires the encrypted message and the user's private key. The message will be displayed to the recipient in plaintext on their device.

The application allows the user to enter optional data to enhance their application experience. This includes COVID-19 test results and the date of the test. Users may enter COVID-19 status information when they are a close contact or test negative for COVID-19 so that their status in visible bubbles changes back from positive to negative from the settings page.

3.4 Limitations

Due to the limitations of time and funds, there are some limitations to our application's hosting and encryption capabilities. Firebase grants its users 10GB of storage before we need to delete messages or older releases (Firebase, 2021). Since messages are only temporarily stored and are deleted after receiving, we did not experience issues during the testing of the application. However, if this application were on a larger scale an issue with storage might arise. Virgil Security also has a limitation, for example, a free application can only have up to 250 users, before reaching a paywall (Firebase, 2021). In the future, it will be necessary to increase the number of users. Furthermore, we were unable to publish the application to the Apple Application Store since it would take several months for approval. Furthermore, it would require the team to upgrade their developer accounts on the Apple website for a fee to submit the request to be granted signing capabilities.

Evaluation Methodology

To test our application, we performed think-aloud interviews with thirty participants, this helped us gauge how individuals viewed the application and their thoughts when using features. This section summarizes the procedure and results of user testing, along with any future recommendations found from the testing for consideration.

4.1 Application Demo & Interview

Think-aloud interviews are a common interview method used to gather data when testing the usability of an application. These interviews require the participant to verbalize their thoughts when testing an application or performing a task. The participant is instructed to speak aloud the steps necessary to complete a task to monitor their comprehension of the application. The goal of these think-alouds was to note individuals' opinions on application features.

After signing a consent agreement, the participant was asked two questions to gauge their concern about privacy in digital contact tracing applications. They were then asked to watch the introduction video of *Bubbles* (viewable at: https://tinyurl.com/bubblesMQP) which highlights the application's goal of privacy and thoroughly explains the security protocols used within the application. After this, the participant performed the think-aloud, verbalizing their thoughts about the application as they used it. The participant was then tasked with uploading mock health information provided by the student investigators. After doing so, they were asked a series of questions regarding application ease of use, these questions can be found in Appendix A.

Due to the minimal risk associated with this research project, we received Institutional Review Board (IRB) exemption, which monitors research involving human subjects. Each

participant consented to their information being used for research. The interviews were performed in person and lasted approximately ten minutes. One student investigator was responsible for conducting the think-aloud, while the other would take notes. The notes consisted of the participant's opinions regarding the application, these notes did not include any personally identifiable information. These notes were written in an encrypted Word file and deleted after analysis.

4.2 Interview Questions and Reasoning

To ensure we asked the right questions to our participants during the testing process, we created a topic map. The topic map listed high-level concepts and corresponding questions that we wanted participants to answer when performing testing.

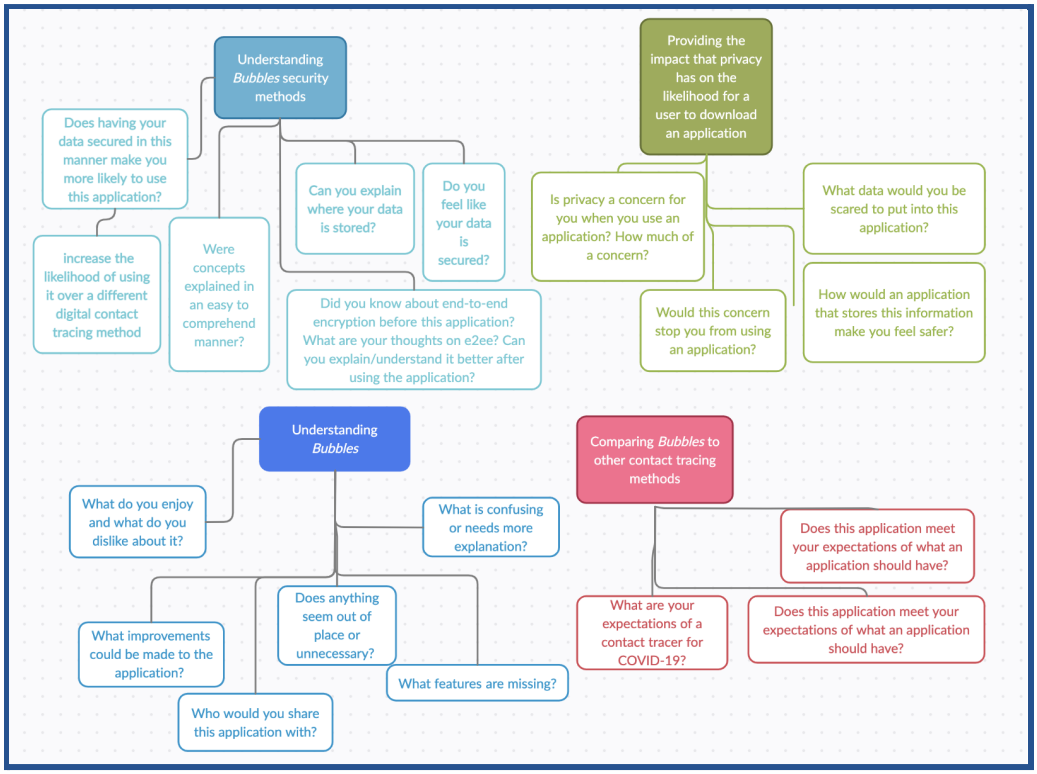

Figure 6: Topic Map displaying High-Level Concepts for Interview Questions

Before conducting the think-aloud interviews, we wanted to gauge the current attitude towards digital contact tracing applications. We asked two questions: one regarding the previous use of other contact tracing applications and the other that scaled users' privacy concerns from one to ten with ten being the most concerned.

After watching the video introducing *Bubbles* and letting the participant navigate around the application, a series of nine questions were asked. These questions fell into four different categories as indicated on the concept map: understanding the application, understanding the application's security methods, comparing the application to other contact tracing methods, and providing impacts privacy has on downloading an application.

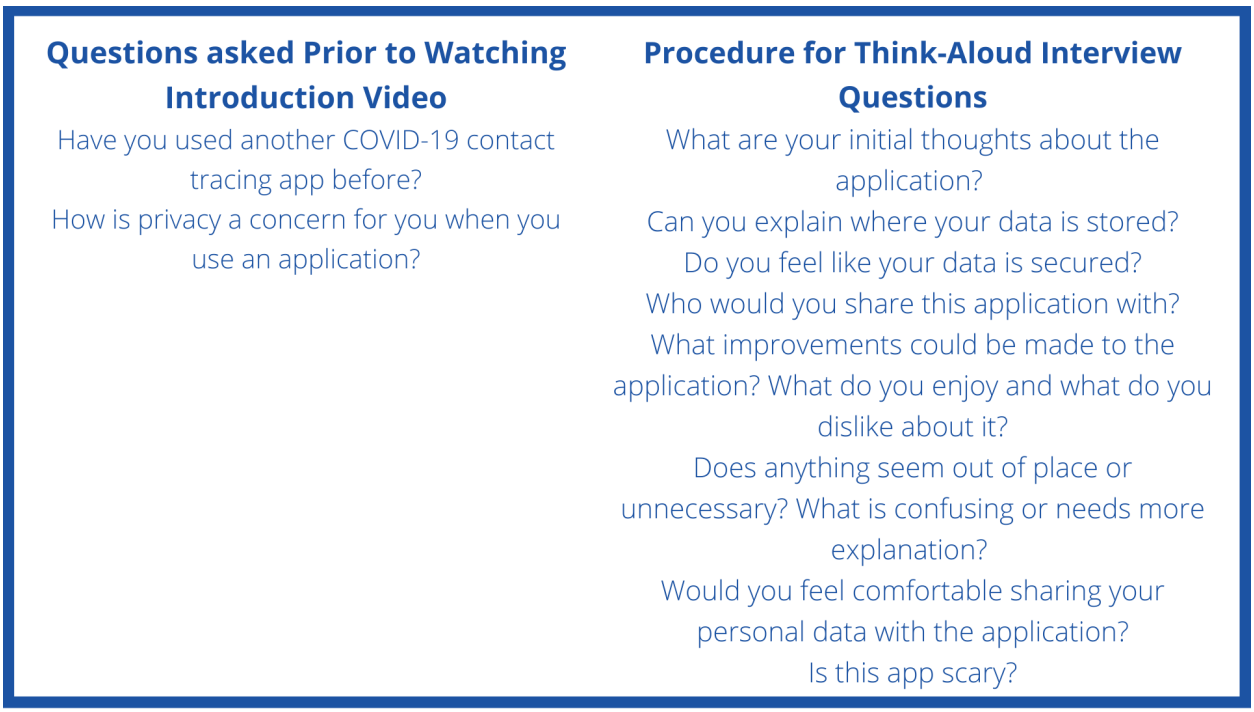

Figure 7: Interview Questions

Evaluation and Discussion

Our testing included thirty undergraduate students, ages eighteen to twenty-three, from Worcester Polytechnic Institute. These participants were prompted to discuss features that would improve the application. The discussion of these features is in the following subsections of the report and the team has created visuals to reflect what the implementations of these features would look like in subsequent releases.

5.1 Evaluation Data & Results

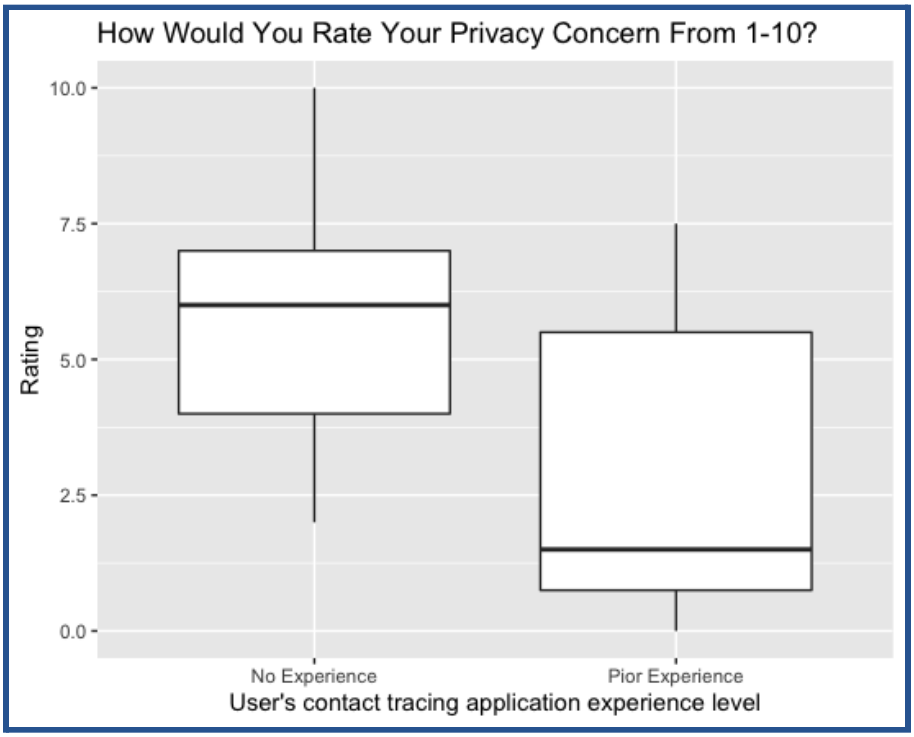

Figure 8: User's Privacy Ratings (1-10 Scale) Results Based on Prior Experience

Interview respondents who have previously used COVID-19 digital contact tracing applications rated their concern with privacy an average of 3.1/10, with 10 being the most concerned about privacy. Those who had not previously used digital contact tracers were slightly more concerned with privacy, rating their concerns a 5.7/10, as seen in Figure 7. Respondents stated they were most concerned about location tracing and data storage, which is consistent with prior work (see Section 2). Of the thirty respondents, ten mentioned the word *information* in their concerns, regarding not wanting individuals to have access to their data. The frequent mention of this word highlights a major concern among users and themes within our data. When asked if the participant felt their information was protected, 100% of respondents said they felt it was protected and felt safe sharing their personal information with the application. Users expanded on their reasoning, saying the application felt "*non-invasive*" and that they felt like "*the app would not do anything with my data that I wouldn't know about, which is something I like about it.*"

To confirm the application design is suitable for a broad range of users and age groups, we asked interview participants whom they would share *Bubbles* with. Many respondents reported they would share the application with their college clubs and the Greek life organizations on campus. Others responded that they would share it with their athletic teams or their friends or family, including their parents, grandparents, or siblings.

5.2 Future Additions

In our testing procedure, participants were prompted to discuss features that would improve the application. The discussion of the best of these features is in the following subsections of the report. If there are to be future iterations, these features would improve the application and should be considered during development.

5.2.1 Notifications

Twenty-five of the thirty participants interviewed stated that notifications would improve the application. Participants stated they would be more likely to check the application if they received notifications that a member of their bubble is a close contact or tested positive for COVID-19. One participant stated that this application could be used "*passively*" and therefore, notifications would be used to remind the user to upload test results and keep their information updated.

When in the planning stages of the application, we wanted to notify users when a member's status changed. This would increase usage by not requiring users to constantly check the application for status changes. When implementing notifications, the team found a security concern that we felt undermined the goal of the project. Hence why it was not included in this release. The application only has access to the user's encrypted testing status when it is pulled from the Firestore server on the application open. To avoid constant background refresh, we did not include data fetching from the server. To notify the user, the fetched data must be decrypted in the background. Although we could temporarily store data locally on the device securely, this will require more data on the device. As concluded from our interview results, the large amount of data stored on the device could scare participants, which defeats the project goal.

5.2.2 Dashboard Page

Feedback was overwhelmingly positive regarding the user interface. Participants remarked the application was "*very user friendly*" and "*appeared clean*." The Dashboard screen, however, raised slight concern. Some participants stated the Dashboard was slightly crowded as each bubble member was listed directly under their associated bubble. This layout could be potentially confusing to application users. One suggestion to increase usability includes displaying the bubble's name as a button to take you to a page that displays bubble members' names and their exposure status.

Figure 9: Mockup of the Dashboard Screen displaying the bubble's name as a button that will navigate to users in the bubble.

Another display layout could include each bubble name by toggling a dropdown menu that displays bubble members' names and exposure status. This would allow all the information to be displayed on the same page, without the potential distraction of viewing different bubble groups at once.

Currently, bubble groups are organized in the order in which the user joined, the most recent group at the top of the page. One participant suggested that perhaps we should order the bubbles based on those that have members recently exposed or infected with COVID-19. This would increase usability as users can easily view the bubbles that have been exposed to COVID-19 without having to scroll through a long list of groups.

5.2.3 QR Code Scanning

Currently, the application allows people to join a bubble by typing in the corresponding bubble name. Although this design worked well for testing and application creation purposes, this will not be feasible if the application were to be adopted by many people or uploaded to an application store. Using the bubble's name as a unique identifier decreases the usability of the application, as it hinders the server from containing two bubbles of the same name. To circumvent this issue, we would implement QR generation upon bubble creation. This feature would allow other users to easily join a bubble by scanning a QR code, which would have its unique identifier on the server instead of the identifier being the name.

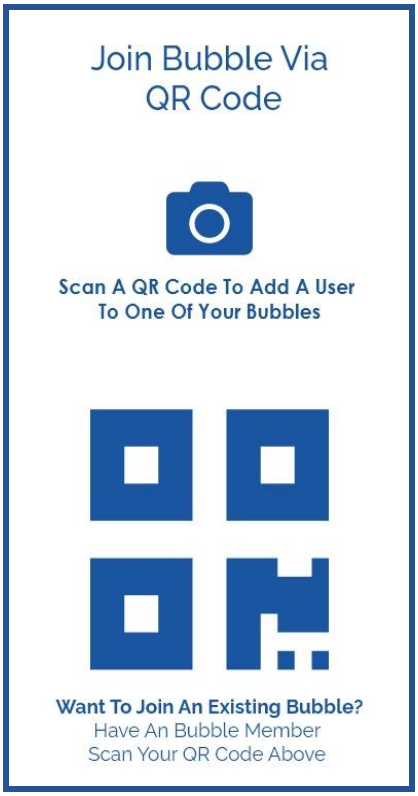

Figure 10: Mockup of QR Code Screen

Conclusions

Privacy issues hinder users from using digital contact tracing applications. The public's main concern includes the requirement of personally identifiable information, such as location services via Bluetooth or GPS, that is necessary to operate these applications. Other concerns include a lack of transparency of how data is secured, a lack of trust that application developers were handling data safely, and an inability to use complex applications. These factors contribute to a low adoption rate.

The goal of *Bubbles* is to create a contact tracing application that is "not scary." The three techniques for meeting this goal are communicating with the user about how the application uses their health data, minimizing the information the application stores, and ensuring the user's health data is only accessible to the user.

Bubbles allows the user to self-report their COVID-19 status, specifically labeling themselves as positive or close contact. To provide the application with accurate data, a user manually enters their COVID-19 status information.

End-to-end encryption is implemented through Virgil Security's public and private key pairs. Data is encrypted on the user's device with the recipient's public key before sending it to the Firebase server. The Firebase will never receive the user's personal information in plaintext. Data will be decrypted on the receiver's device with their private key.

Although data is transferred following proper encryption protocols, we want to ensure users have a high-level understanding of how their information is kept secure. Users must comprehend that their information is safe for them to trust the application. To accomplish this, we created a short introduction video explaining how our application uses encryption in a way

that non-technical users will find easy to comprehend. Security concepts are also explained within the application.

To make *Bubbles* easy to use, we created a sleek, user-friendly interface with minimal screens to navigate. When developing this interface we had many iterations of low-fidelity and high-fidelity prototyping.

To determine the usability of *Bubbles*, we conducted think-aloud interviews. Participants were tasked with uploading mock health information provided by the student investigators. The goal of these think-alouds was to note individuals' opinions on application features. We received very positive feedback about both our application security and user interface. 100% of our participants noted that the application was "not scary," proving *Bubbles* accomplishes its main goal. Additionally, each of the participants responded they felt their information was secure.

Acknowledgments

We would like to express our deep gratitude to Professor Patrick Schaumont, Professor Robert Walls, and Professor Oren Mangoubi, our MQP advisors, for their patient guidance, enthusiastic encouragement, and useful critiques of this research work along with our survey participants for their time and insights on our application.

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Addressing Privacy Concerns of COVID-19 Contact Tracing

By

Alexa Freglette

A Major Qualifying Project (MQP)

Submitted to the Faculty

of the

WORCESTER POLYTECHNIC INSTITUTE

In partial fulfillment of the requirements for the

Degree of Bachelor of Science

in

Professional Writing

by

Alexa Freglette

May 2022

Approved by: Kevin Lewis, Professional Writing

Table of Contents

1. Abstract

Manual contact tracing has been a useful way to mitigate the COVID-19 pandemic. However, this technique is laborious and depends on the infected individual's ability to recall their close contacts. Recently, digital contact tracing applications have emerged as a more efficient way to track close contacts. However, due to location privacy issues and the substantial amount of personal data collected, users have been less inclined to use these applications. For these applications to be useful, they must receive a higher adoption rate.

In this Professional Writing Major Qualifying Project, I explore the privacy concerns of both contact tracing forms. Through research, interviews, and surveys, I conclude that privacy is the largest concern of digital contact tracing applications.

2. Introduction

Contact tracing is the procedure of identifying those who have encountered an individual with a highly transmissible disease. Contact tracing is universally defined as identifying, monitoring, and supporting those who may have been exposed to a person with a contagious disease, for example, COVID-19. Nations have turned to contact tracing to slow the spread of COVID-19. Contact tracing aims to identify those who contract the disease and potential spreaders. COVID-19 is highly contagious, hence the importance of mitigating its spread.

Given the importance of quick action against the COVID-19 pandemic, contact tracing is crucial. Public health officials and organizations, such as the Center for Disease Control and Prevention (CDC), use contact tracing to identify sources of potential infections while vaccines are being developed and distributed. Contact tracing is an effective way of protecting individuals; however, there are ways to improve upon this strategy.

The goal of this Professional Writing (PW) Major Qualifying Project (MQP) is to communicate the differences between manual and digital contact tracing with the hopes of illuminating these differences to application developers, health officials, and the public. Furthermore, I will delve into the fears and ethical challenges that both tracing methods present. This project focuses on the ethics of contact tracing during the COVID-19 pandemic. The corresponding project report includes the following information about my project:

- Background, which explores specific ethical and privacy issues that exist for both manual and digital contact tracing
- Research methods, which defines the methods I used to further research and find solutions for these problems

- Research results, where I make inferences and observations based on the research I conducted
- Conclusions, where I summarize my findings
- Recommendations, where I offer solutions to the ethical and privacy concerns that currently exist and explain a middle-ground approach to contact tracing

3. Background

COVID-19 spreads quickly from person to person. It has been a vigilant effort of all those in charge to control its spread. The infected can transmit COVID-19 through the air, such as when talking, even without symptoms. If another person breathes in this air, they can be potentially infected with COVID-19. The most common way to spread COVID-19 is through close contact—within 6 feet away from an infected individual for fifteen minutes or more over a twenty-four-hour period. The infected individual could spread COVID-19 starting from two days before they are symptomatic until they meet the criteria for ending isolation. If both individuals were wearing masks correctly and consistently or were outdoors, they are not considered close contacts.

2.1 Challenges with Mental Health and Stigma

The COVID-19 pandemic has caused mass hysteria as people were forced to navigate without a sense of safety and hope. The pandemic has affected all areas of people's lives; however, the global impact on society's mental health has been incredibly profound. Stigma and fear are two aspects that present major barriers in healthcare, social marginalization, distrust in health authorities, and distortion of the public's view of risk. These factors have caused panic among social groups (Kar, Arafat, Kabir, et al., 2020). Due to the high infection and fatality rate, many people have felt high stress, anxiety, and helplessness. As nations instated lockdowns forcing citizens to stay at home, feelings of uncertainty, boredom, and disappointment surfaced.

2.2 Use of Manual Contact Tracing During the COVID-19 Pandemic

Manual contact tracing begins with a phone call from a contact tracing team member. The team identifies individuals the infected person was in contact with within the past 48 to 72 hours. These contacts are often notified about their exposure via phone call. Depending on the close contact's vaccination status and if they have previously contracted COVID-19, they may be advised to isolate to prevent the disease from further spreading, as well as given a warning of common symptoms.

2.3 Ineffectiveness of Manual Contact Tracing

Traditionally, manual contact tracing involves a trained team conducting interviews with the infected. Using information from interviews, this team learns who the infected individual recently encountered. The contact tracers then inform those deemed "close contacts" of their exposure, ask them to quarantine, and explain the necessary steps to follow, such as testing protocol. Furthermore, contact tracers refer services and resources to those diagnosed with COVID-19. Manual contact tracing offers a sense of support and understanding. However, it can be incredibly labor-intensive for the contact tracing team as the interviewing process is lengthy.

Manual contact tracing is an inefficient way of determining close contacts, as it is dependent on one's ability to recall information about those that may have been exposed. Furthermore, the information may not be accurate. For example, if an unknowingly infected individual was traveling publicly, such as on a bus or train, it would be impossible to recall each person they were near.

2.4 The Ethics of Digital Contact Tracing

Recently, mobile phones and other digital information technology have aimed to improve the contact tracing process. The main forms of this are GPS, which uses satellites to find the location of a person's phone within a limited range, and low-wave Bluetooth, which detects a person's location within 30-40 feet. This method of tracking does not account for individuals following social distancing guidelines. Digital contact tracing can result in high chances of false contact notifications. The use of digital contact tracing has caused major concerns about data privacy; and therefore, has not received much traction.

4. Research Methodology

This project requires a detailed literature review, interviews, and surveys.

3.1 Literature Review

I performed extensive background research to develop a better understanding of the COVID-19 pandemic and contact tracing. This allowed me to formulate the topics of my research and cultivate the questions I wanted my project to answer. I needed to compile and understand previously written research on COVID-19 to communicate informed recommendations on how to alleviate fears of contact tracing.

To identify current attitudes towards COVID-19 and contact tracing, I researched databases such as the WPI Gordon Library and Google Scholar. Topics I searched for included:

- Stigma Related to the COVID-19 Pandemic
- Health Risks Related to the COVID-19 Pandemic
- Previous Pandemics
- Privacy Concerns and Public Trust Related to Contact Tracing during the COVID-19 Pandemic
- Ways to Increase Public Trust During the COVID-19 Pandemic
- Politics Related to the COVID-19 Pandemic
- Countries' Policies Relating to the COVID-19 Pandemic.

Using these key phrases, I was able to find numerous peer-reviewed journal articles and papers published within the past 2 years.

3.2 Surveys

I used surveys to collect a large amount of data about people's opinions of contact tracing and the COVID-19 pandemic. The goal of these surveys was to hear from the public about their COVID-19 experiences, specifically focusing on digital contact tracing. The surveys consisted of nineteen questions, fourteen were multiple choice and five were short responses. The short response questions allowed participants to elaborate on the previously answered multiple-choice responses. Although a participant's consent was required to begin the survey, no other questions were mandatory. This was to ensure participants did not feel pressured to provide any information they were uncomfortable with sharing. Before publishing, the survey and consent agreement received Institutional Review Board (IRB) approval. This group is responsible for monitoring research involving human subjects. I used the online survey software Qualtrics to conduct my surveys. I posted these surveys on platforms such as LinkedIn and SurveyCircle to receive more traction. Before beginning, each participant was required to consent that their information could be used for research.

Through these survey results, I learned about my participants' feelings towards the COVID-19 pandemic and contact tracing. When creating survey questions, it was important to determine information already known and how responses could aid me in my research. I asked precise, unbiased questions to receive feedback sufficient for my project scope and not sway my participants. Once established, I performed Root Cause Analysis—determining what causes fear of digital contact tracing applications, why this fear exists, and what can be done to reduce it.

By combining both multiple-choice and short answer questions, my survey participants were able to share thoughts about contact tracing improvements. All survey questions are

included in Appendix of the report. The questions below are high-level concepts of what I wished to learn from these survey results.

- Is there a stigma surrounding the COVID-19 pandemic?
- What is the root factor the COVID-19 pandemic stigma?
- If a participant contracted COVID-19, how did they feel about the manual contact tracing process?
- If a participant has used a digital contact tracer to track if they have encountered someone who has contracted COVID-19?
    - If not, why hadn't the participant used this form of contact tracing?

3.3 Interviews

I used interviews to gain a better understanding of my participants' opinions and experiences with both forms of contact tracing. Before conducting my interviews, I received Institutional Review Board (IRB) approval. Before beginning, each participant was required to consent that their information could be used for research. I developed open-ended interview questions to foster in-depth responses that illuminated the stigma around contact tracing.

From these questions, I hoped to obtain a better understanding of the stigma surrounding contact tracing. Similar to my survey goals, I wished to understand if there exists a fear of contact tracing and, if so, the root of this fear. I provided my interview participants with the opportunity to share how contact tracing may be improved upon.

All interview questions are included in Appendix of the report, below are some example questions:

- How has the COVID-19 pandemic impacted your life?
- Do you know what a digital contact tracer is?
- What would need to be done to make you want to use a digital contact tracer?
- How would you feel if it was required by your country to use a digital contact tracer?

5. Research Results

The following section captures the results of the research conducted throughout my MQP.

4.1 Literature Review

This section provides the findings of my literature review which focused on exploring the public attitude towards COVID-19 and contact tracing. I also explored the factors that contribute to these feelings.

4.1.1 Stigma Related to the COVID-19 Pandemic

Throughout the pandemic, there has been anxiety about the unknown. People's attitudes have been negatively impacted, resulting in discrimination and a reluctance to participate in contact tracing. This affects contact tracing's efficacy as it depends on the public's willingness to participate in the tracing process.

One critical issue highlighted by the lack of public health employment is the language and cultural barrier. Due to the short supply of bilingual contact tracers, foreigners have had difficulties throughout the pandemic. The short staff is unable to offset the high amount of those contracting the disease whose primary language is not English.

There exists a stigma surrounding the rising inequality and pandemic-induced hardships. Public health involvement, such as digital contact tracing, can potentially reduce racial and social-economic gaps in morbidity and mortality. However, if officials only focus on those who are most privileged, this involvement will worsen health disparities (Perry, 2021).

4.1.2 Health Risks Related to Digital Contact Tracing during the COVID-19 Pandemic

COVID-19 has increased mental health-related risks including stress, anxiety, morbidity, and mortality rate throughout the world. Citizens are worried about critical disease information—such as virus incubation period, transmission route, treatment, and safety measures. To prevent exposure, countries have emphasized the importance of isolation; however, this has had harsh impacts on an individual's wellbeing. Isolations have increased anxiety and insecurity about the future, which have further declined mental health (Kar, Arafat, Kabir, et al., 2020).).

A prospective study in Japan discovered COVID-19 contact tracing applications may reduce fear, worry, and psychological distress surrounding the pandemic. The study examined an application implemented by the Japanese government to determine psychological grief using the Psychological Distress Scale (K6+) scale. The researchers concluded the application did not significantly influence the participants' severe psychological stress. They hypothesized participants might cope better with the pandemic over time, reducing their stress, even if they are still worried. Although small, it was determined that a contact tracing application decreases the prevalence of mild psychological distress by 15% on average compared to non-users. The researchers stated this may be more influential on a large scale. Furthermore, they concluded downloading a digital contact tracing application may serve as a way for their participants to cope with the COVID-19 virus. In their opinion, this could create a sense of control, lowering a participant's distress (Kawakami, Sasaki, Kuroda, et al., 2021).

4.1.3 Combining Manual and Digital Contact Tracing

The effectiveness of digital contact tracing is limited by the application's users. For the application to work to its potential, both the infected and their close contacts would need to have previously downloaded the application. The research article, "Effect of Manual and Digital Contact Tracing on COVID-19 Outbreaks: A Study on Empirical Contact Data" combined the potential effectiveness of contact tracing methods. The researchers discovered contact tracing is more effective when partially alleviated, therefore using manual and digital contact tracing in tandem should decrease the epidemic size. "The combination of [manual contact tracing] and [digital contact tracing] is able to suppress outbreaks at limited cost if the app adoption and [manual contact tracing] efficiency are sufficiently high" (Barrat, Cattuto, Kivelä, et al., 2021). Manual contact tracing can potentially reduce epidemic size linearly with the fraction of contacts properly recalled. According to the simulation, digital contact tracing can only reduce the epidemic quadratically with each additional application adopter, due to the necessity of downloading the application on both devices. This study confirmed strong privacy protocols are a possible way to increase the adoption rate and have a strong impact on digital contact tracing applications (Barrat, Cattuto, Kivelä, et al., 2021).

4.1.4 Privacy Concerns and Public Trust Related to Contact Tracing during the COVID-19 Pandemic

Contact tracing has been a critical resource in slowing the spread of COVID-19. Digital contact tracing, specifically, has been identified as a key technology that can mitigate the spread of the pandemic. Researchers hope digital contact tracing will remedy the challenges of traditional contact tracing, for example, by decreasing labor.

There are data and privacy concerns surrounding the GPS and Bluetooth technologies used by digital contact tracers (Grekousis & Liu, 2021). Jennifer Oliva, an associate professor of law at Seton Hall University School of Law, claims "location tracking is highly invasive because it tracks… [a user's] movements such as going to a church or a birth control clinic and who [they] associate with" (Lehmann, 2020). The technology's invasiveness is a critical reason digital contact tracing has not received much traction.

Application transparency is another large concern for the public. Developers, such as Colm Harte—an Irish software developer that built the country's COVID-19 contact tracing application—stated that they are created transparently with protected open-source backend code. However, the public is not convinced. Questions are often asked regarding who controls data tracking and how data will be used.

The public is concerned about privacy violations when sharing personally identifiable information. Privacy advocates have apprehensions that data may not be anonymous which can lead to abuses of civil rights. Risks of this would include stolen personal data and unauthorized users gaining access to identifiable GPS and Bluetooth data. These are core reasons digital contact tracing has not been widely accepted in the United States (Sowmiya, Et Al., 2021).

Due to these ongoing concerns, there has been a low adoption rate of digital contact tracing applications. Specifically raising alarm is the "…indiscriminate collection of personal information, chronic privacy breaches, and lax attitudes towards individual privacy in the private sector [which] have eroded public trust in digital technologies" (Bengio, Janda, Yu, et al. , 2020). In a survey regarding the security and privacy issues of COVID-19 contact tracing applications, 49% of participants who said they would not use a digital contact tracing application cited privacy concerns as being their main reason. (Sowmiya, B. Et Al., 2021). In

theory, digital contact tracing can decrease the spread of COVID-19; however, to reach its full potential the technology must be widely adopted and used.

4.1.5 Ways to Increase Public Trust During the COVID-19 Pandemic

The public has turned to medical health professionals for support during unprecedented times. Medical professionals, especially COVID-19 contact tracers, have been expected to explain the pandemic and its spread in easy-to-understand language, as well as offer support to those in need. This has been especially important to those whose first language is not English.

To assist in public trust, staff members must understand all interactions are confidential. For public security and individual safety, staff should not disclose information about a patient when filing a contact tracing case. To assist in this, staff members have turned to COVID-19 specific training which includes protocols and training for high-risk individuals. Medical staff is also provided with the knowledge of complex situations and offered crisis training.

For the success of digital contact tracing applications, it will be critical to build public trust and ensure information is secure. According to the Internet Policy Research Initiative at the Massachusetts Institute of Technology, it is important for digital contact tracing applications to include privacy, design flexibility, and rapid notification and integration. Additional ways to increase public trust in digital contact tracing applications include the user consenting to each step when sharing data (2020). This will be particularly helpful if users feel anxious about providing personally identifiable information.

4.1.6 Congressional Policy Issues Related to Contact Tracing

As the pandemic progresses, Congress must decide how to guide the United States in its efforts to retain public safety and health. The Congressional Research Service (CRS) highlighted four issues regarding the federal response to COVID-19 contact tracing: leadership and coordination, trust, privacy and security, and evaluation. The CRS is a public policy research institute that serves Congress by providing comprehensive research and analyses with a confidential, nonpartisan bias. When offering recommendations to Congress, the research team acknowledged most contact tracing efforts were led by the CDC. It questioned whether the federal government should have a bigger role in contact tracing efforts to help create a standard for guidelines and tools. The team stated Congress must decide how they can obtain public trust while encouraging new technology adoption and the need for individuals' personal data. Furthermore, Congress must determine if new standards are necessary regarding the privacy and security of contact tracing information, particularly involving an individual's health information. Congress will need to standardize a digital contact tracing regulation and evaluation process; each state has adopted different ways to regulate to spread of COVID-19. The United States government must determine the best implementation and extend it to the rest of the country (Congressional Research Service, 2020).

4.2 Surveys

The survey portion of this MQP included sixty-three people whose identities were kept anonymous. The following subsections summarize my survey results.

4.2.1 COVID-19 Life Impacts

I wanted to address the impact COVID-19 had on participants' lives. Survey results show COVID-19 had negatively impacted 92% of participants. When asked how, respondents highlighted COVID-19's detrimental effects on their mental, emotional, physical, and social well-being. Important events, such as college and job opportunities were missed due to lockdowns and lack of social interactions.

When asked if there was a stigma surrounding the COVID-19 pandemic, participants overwhelmingly agreed. In this survey "stigma" was defined as casting an adverse approval around a specific group or actions of distinguishing characteristics. As this question is less definitive than the other questions asked in the survey, there were five possible responses. Figure 1 shows the comparison of responses about the COVID-19 stigma.

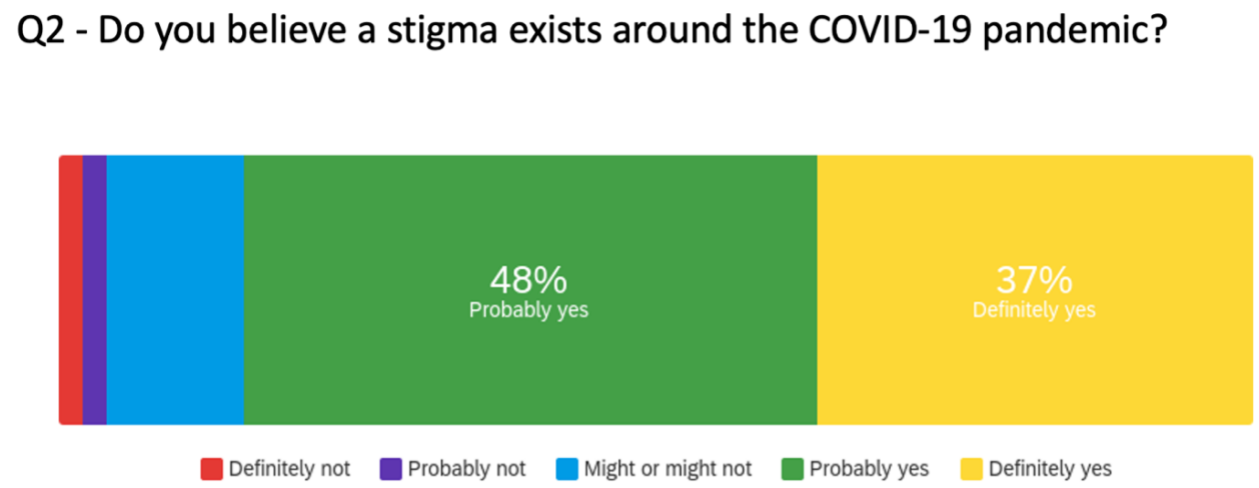

Figure 1. Response to survey question two, "Do you believe a stigma exists around the COVID-19 pandemic?"

As this figure displays, 85% of survey participants responded "probably yes" or "definitely yes" to the question. While around 4% of participants responded "definitely not" or "probably not."

The negativity towards COVID-19 was credited to a misunderstanding about the virus and its transmission. Other notable negative feelings stemmed from the varying degrees of caution, for example, differing opinions on vaccination status and wearing masks. Some participants believe the disease will develop into a common viral infection, such as the flu, and should be treated as such. Others highlighted the severity of COVID-19, commenting that it is still a serious threat. Most mentioned how continuously hearing about the pandemic has negatively impacted their mental health.

4.2.2 Public's Thoughts on Manual Contact Tracing

Through these surveys, I gauged the current manual contact tracing process. Of the sixty-three survey participants, only seventeen had contracted COVID-19. Nine participants were contacted, seven were not, and one did not wish to provide information on if they were contacted by a manual contact tracing team. Interactions with contact tracers were fairly positive. Results illustrate each participant was contacted in a timely manner; all but one claimed they were told about resources. About half of the contacted participants stated the call was helpful, although most remarked the interaction could be improved upon. When prompted about improvements, results show the public wished the contact tracing staff was more accommodating to individual needs. Furthermore, some believe manual contact tracing is an invasion of privacy. Other notable information shared was some "close contacts" were not notified by manual contact tracers.

4.2.3 Public's Thoughts on Digital Contact Tracing

The survey questions captured the public's attitude regarding digital contact tracing applications. Figure 2 displays participants' responses according to if they use or have previously used a digital contact tracer.

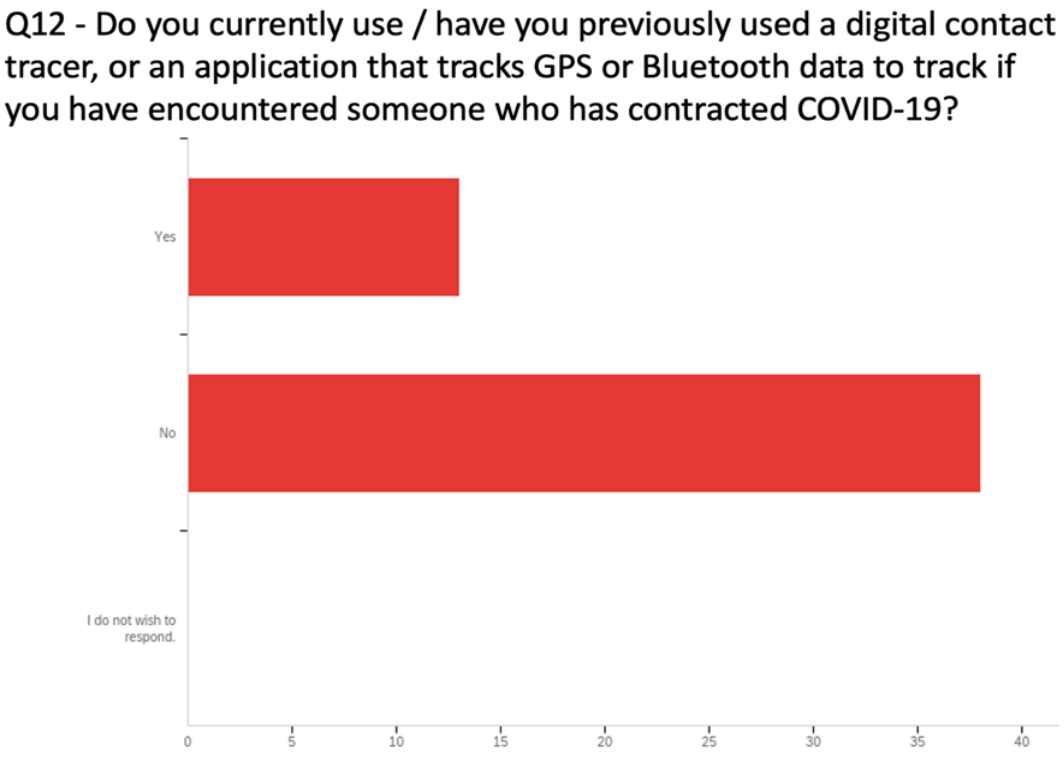

Figure 2. Response to survey question twelve, "Do you currently use or have previously used a digital contact tracer…?"

As shown above, 75% of the participants do not use and have not previously used digital contact tracers. Furthermore, of the thirty-eight people who reported not using contact tracers, 62% claim it is because they were unaware of its existence. Another notable reason is due to location tracking services, such as Bluetooth and GPS. Specifically, some participants fear large corporations and governments having this location data. Others worry about false positives and quarantining without reason. Additional reasons for not using digital contact tracers include misunderstandings about the application's downloading process, functionality, and collection of data. Some participants worried about the secure transfer of private health information.

4.3 Interviews

Through interviews I heard about my participants' COVID-19 experiences, specifically focused on digital contact tracing. Before conducting the interviews, I received Institutional Review Board (IRB) approval, which monitors research involving human subjects. Those interviewed consented to their information being used for research purposes. The interviews were carried out on Zoom, voice recorded, and then transcribed. Once the transcription was complete, all other media was deleted. The interview portion of my research project included five people, whose identities—besides age, gender, and occupation, if they agreed—were kept anonymous. There were two men and three women involved in my interviewing process, with ages ranging from twenty to sixty. Most questions were answered similarly; however, responses regarding privacy concerns of digital contact tracing received mixed results. My interviewees were split on the balance of public well-being and individual privacy. The following subsections summarize my interview findings.

4.3.1 COVID-19 Life Impacts

Although each interviewee was affected by the pandemic differently, many had similar experiences. Participants explained the COVID-19 pandemic caused abrupt life changes. They had to abandon their usual lifestyle and focus on staying healthy. Each interviewee mentioned their anxiety about the future and the unknown. Three of the five were forced to work from home and all were unable to see their family and friends for very long periods of time. All interviewees mentioned their struggle to stay as safe during the unprecedented time.

One of the interviewees remarked that the response to COVID-19 had changed over time. She believes society has become more at ease, or perhaps has come to terms, with the disease as

more information is researched and becomes known. She mentioned society transformed from ostracizing one another to understanding the importance of resuming normalcy. In her opinion, if an individual is precautious, they should resume daily life again.

4.3.2 Defining a Digital Contact Tracer

Most of my participants were unaware of what a COVID-19 digital contact tracer was. When asked about prior knowledge of digital contact tracers, three of the five participants responded that they had no understanding of how digital contact tracers worked. Two of those who knew of the applications were under thirty years old and the other was a medical professional. The other two participants had slight knowledge but admitted they did not fully understand the applications' usages.

One participant mentioned applications such as the NYSCovid and the Apple Exposure Notifications. However, explained they did not understand how to use them properly. Although the participants who downloaded the application thought they had followed the instructions, they did not receive any notifications regarding their exposure, even after being exposed to COVID-19.

Participants discussed the security risks of digital contact tracers. One response included calling the applications an "invasion of privacy," and believed more emphasis should be placed on the individual rather than public wellbeing. Some interviewees remarked on other privacy concerns such as intrusion of data and information on location. Other issues included hackers acquiring personal data.

Participants were concerned about the accuracy of digital contact tracers and their ability to mitigate the pandemic. One stated, "…until we can figure out how to pinpoint where the next steps of the virus are, we will always be behind..." Another participant considered accuracy issues of contact tracing locational awareness. He believed quick encounters with an infected individual, for example walking near someone outdoors, should not trigger the digital contact tracing application. Instead, the applications should consider more details such as proximity, time, and if one or both individuals are wearing masks.

4.3.3 Increase Contact Tracing Use

When asked how to improve digital contact tracers, participants emphasized privacy. One stated it was of utmost importance that data is kept "anonymous." Participants highlighted their fears of compromised personal health data, for example through a data breach. One interview participant stated developers must "guarantee [third parties] will not get to any of [users'] data. [The application should] track [the COVID-19 virus] and the data [will] not be shared with anybody..." Others stated developers must guarantee secure data unable to be accessed by outsiders.

To increase the adoption rate, participants revealed applications must accurately detect the virus. When interacting with an infected individual, participants expect their phones to notify them of exposure. However, interviewees revealed their phones were not currently doing so. One participant mentioned applications should add external factors, such as proper mask usage and vaccine status, to provide more accurate exposure notifications when using digital contact tracers.

One participant recommended digital contact tracing applications should constantly run in the background of a phone, as opposed to only tracking location when the application is open. During the interview, she noted constant access to data may result in some privacy issues; however, believes the constant collection of information is important if the application intends to focus on accuracy and public health wellbeing.

4.3.4 Mandated Digital Contact Tracer

In response to a hypothetical United States mandate of digital contact tracing applications, participants unanimously agreed that forcing citizens to use contact tracers would invade privacy. One participant commented this would be an “overreach of government power” and considered how it may “infringe on people's free travel.” In addition to comments about invasiveness, some interviewees mentioned enforcing these applications could benefit society by creating a definitive means to track the disease. They believe if everyone participates in tracking the virus, exposure notifications would increase in accuracy and more effectively mitigate the spread of COVID-19.

5. Conclusions

Based on my research results, I have drawn the following notable conclusions of my research.

5.1 Infringement of Privacy

Privacy is the largest concern of digital contact tracing applications. Privacy is specifically important because it protects information that individuals do not want to be shared publicly. As presented in "A Survey on Security and Privacy Issues in Contact Tracing Application of Covid-19" by Sowmiya et al. privacy concerns cause a decrease in the digital contact tracing adoption rate, which hinders its accuracy. This is one factor that has prevented it from becoming an effective form of contact tracing.

After analyzing interview conversations and survey results, I was able to conclude the public believes governments should emphasize an individual's right to privacy over the community's well-being. This was conclusion was specifically discernable during interviews when each of my respondents reacted negatively to the hypothetical digital contact tracing mandate. One participant thought the idea would "infringe on people's free travel." The public's opinion on this enforcement was further highlighted through survey results as participants claimed they feared the government having their location data.

5.2 Lack of Understanding

Currently, there is a lack of understanding about digital contact tracing. This was especially clear when 60% of my interview participants did not understand how to use contact

tracing applications. I determined this stems from minimal available resources. The absence of information has led to public doubt in the functionality and effectiveness of digital contact tracers, causing negative attitudes towards the applications. Throughout my research, the most common issue participants mentioned was not knowing about digital contact tracers.

5.2.1 Lack of Public Knowledge

Survey and interview results indicate a large majority of the population misunderstands digital contact tracing applications, specifically their functionalities and information storage techniques. Although interview participants mentioned applications, such as the Apple Exposure Notifications, they did not understand how to use them. Furthermore, one survey participant commented that many people have never heard of digital contact tracing. It is evident that there is a lack of public knowledge regarding digital contact tracing.

5.2.2 Lack of Widely Available Information

The minimal understanding of digital contract tracers is rooted in the lack of widely available information. There is especially little information regarding locational awareness technologies and secure data transfer. This has caused an increase in anxiety surrounding digital contact tracers. Individuals fear their personal health information could be stolen by hackers and used for malicious purposes, for example in the case of a data breach. These fears have been mentioned in all forms of my research. To provide a comfortable user experience, these fears must be remedied.

5.2.3 Lack of Knowledge Causing Doubt

The public doubts digital contact tracers' usefulness. Specifically, they are unconvinced about their accuracy and ability to mitigate the spread of COVID-19. Results of surveys and interviews show concern regarding applications' precision and ability to trace COVID-19. Many applications do not consider factors such as proper mask-wearing and time spent together. Some believe technology will never be able to track the virus, especially due to COVID-19's contagiousness. The success of digital contact tracers will be dependent on the public trusting the application.

5.3 Confusion of Application Working Properly

Throughout my study, some individuals noted they understood contact tracing applications, but it did not function as expected. For example, when participants encountered an infected individual, they expected their device to send an exposure notification; however, the device did not send any notification. These users are not alone in their experiences. I conclude either these applications are not working correctly, or the developer did not provide proper instructions on application usage. One cannot expect the public to use an application that does not work. Similarly, the public cannot be expected to use an application that does not have clear instructions for use.

5.4 Digital Contact Tracing Stigma

The stigma surrounding the pandemic has caused a myriad of mental health-related issues. It has also resulted in discrimination against the infected. These factors have negatively

impacted digital contact tracing's efficacy as it is dependent on the public's willingness and ability to participate in the tracing process.

5.4.1 Stigma Relating to Mental Health

The pandemic has heightened hardships for many people affecting them mentally, emotionally, physically, and socially. It has caused the public to abruptly change their daily life routines. This adjustment creates anxiety about the future and the unknown. My research results have shown feelings about the pandemic were overwhelmingly negative. According to these results, about 93% of survey respondents stated COVID-19 had adversely impacted their life. Participants stated reasons such as the initial minimal information about the transmission rate, ongoing fear that one might contract the virus, and loss of sense of community. As shown in the article "The Effects of Downloading a Government-Issued COVID-19 Contact Tracing App on Psychological Distress during the Pandemic among Employed Adults: Prospective Study" an accurate digital contact tracer may decrease one's anxiety. As this would provide individuals with more accurate knowledge of their exposure to COVID-19.

Minimal social interactions due to lockdowns could also cause mental health issues. I determine there has been a cyclic pattern of anxiety during the COVID-19 pandemic. At the beginning of the pandemic, anxiety increased. As mask restrictions and lockdowns were lifted, most people's anxiety decreased. However, concern skyrocketed as mandates were reinstated, causing intensified anxiety and a downward spiral of mental health issues.

5.4.2 Stigma Relating to Underserved Communities

The pandemic has caused a rising inequality that disproportionately affects underserved communities. Certain populations have faced an increased risk of contracting COVID-19 due to economic and social circumstances, limited access to testing and treatment, and underlying health conditions. If implemented properly, digital contact tracing can reduce racial and social-economic gaps in morbidity and mortality. To do so, contact tracing programs must be inclusive of underserved communities.

5.5 Effectiveness When Combining Digital Contact and Manual Contact Tracing

Digital contact tracing would be most effective when used in tandem with manual contact tracing. As mentioned in the article "Effect of Manual and Digital Contact Tracing On COVID-19 Outbreaks: A Study On Empirical Contact Data", contact tracing is more efficient in situations where the pandemic is partially alleviated. Using both forms of contact tracing would increase an individual's knowledge of their exposure to COVID-19, therefore better mitigating the pandemic's spread.

5.6 Government Trust Levels

The public is dissatisfied with the government's enforcement of digital contact tracing, specifically the United States government as most of my research participants were US citizens. I conclude there is an overall lack of trust between the United States government and its citizens' personally identifiable information. A large majority of the population believes the United States government will use the information curated from digital contact tracers, for example, location

services, to spy on them and track their movements. This may be a result of the lack of publicly available information on digital contact tracers, specifically their data transferring and encryption protocols.

The United State government is aware of this suspicion and has been implementing laws and guidelines to increase public trust. It will be critical to properly execute these plans.

6. Recommendations

Based on the conclusions I drew in the previous section I formed the following recommendations.

6.1 Increasing Public Knowledge

There is a lack of public knowledge regarding digital contact tracing. I recommend having information more widely available, specifically on online platforms such as the CDC website. Articles should provide knowledge of application functionality and procedures, specifically describing how digital contact tracing works. In addition, articles should be written about how personal data is encrypted to ensure secure data transfer. These articles must receive widespread attention to increase awareness of digital contact tracers. To expect widespread approval, there must be an increase in public knowledge. This will increase awareness and confidence in the application.

6.2 Decreasing Anxiety

To decrease anxiety around digital contact tracers, developers must clearly document application functionality and use. Users worry their personally identifiable information may be stolen. Therefore, developers must utilize secure communication methods, such as end-to-end encryption. Another way to minimize users' anxiety is by thoroughly explaining application protocols to safely transfer health information. This information should be easily accessible, such as locating it in application store description or on a page within the application.

Another area of concern is the amount of data required for application functionality. Developers should provide reasons for requesting data; all unnecessary data requested should be optional. The language to describe these processes must be non-technical and concise to ensure users will comprehend it. From this, users should understand how their data is secure, as well as a third party's inability to retrieve data.

6.3 Increasing Public Trust

For digital contact tracing applications to be useful, there must be an increase in the adoption rate. For this to occur, the public must trust the application. During interviews, participants mentioned to increase the adoption rate, applications must accurately detect the virus. The article "Effect of Manual and Digital Contact Tracing on COVID-19 Outbreaks: A Study on Empirical Contact Data" states another way to achieve this is through strong privacy protocols. When building a foundation of trust for a digital contact tracing application, an individual's data must be kept private.

6.4 Ensuring Equal Opportunity

Digital contact tracing applications must benefit all community members. Developers must consider the discrimination and bias of underserved communities as it relates to the healthcare system. Applications should support multiple languages and offer language assistance. This may mitigate some users' fears and reduce barriers to application inaccessibility. Digital contact tracing tools that are of minimal cost will ensure equal opportunity for use. Underserved communities must have the same access to digital contact tracing tools to ensure all community

members will benefit and assist a larger audience.

6.5 Implementing in Tandem with Manual Contact Tracing

Digital contact tracers work best when combined with another form of pandemic mitigation. Therefore, pairing digital and manual contact tracing will be the best way to mitigate COVID-19. Combining both forms of contact tracing will capture a better awareness of one's COVID-19 exposure status. Digital contact tracers will notify individuals if they have been in close contact with those infected with COVID-19 and manual contact tracing will provide individuals with emotional support and resources that can be useful during difficult times. An infected individual can report their close contacts to a manual contact tracer, and those they don't know would be notified via a digital contact tracing application. By increasing an individual's knowledge of their exposure to COVID-19, the pandemic's spread can be mitigated.

6.6 Standardizing Guidelines

It is necessary for the government to take a more prominent role in its support of digital contact tracers. Firstly, the government must inform its citizens that the United States government is not tracking their locations, as this is the main fear mentioned throughout my research.

The government must create a standard of security protocols for application developers to use when creating digital contact tracing applications. This standard should ensure that health data is transferred securely, for example using end-to-end encryption. A concrete guideline of

security protocols for developers to follow has the potential to increase the public's comfort level and subsequently raise the adoption rate of digital contact tracing applications.

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8. Appendix

IRB Consent Form

Addressing Privacy Concerns of the COVID-19 Contact Tracing There are two parts to this survey, the first (below) is a consent agreement to take the survey which requires your electronic signature. This form presents information about the study so that you may make a fully informed decision regarding your participation.
The second is the survey which is being conducted to understand the public's feelings towards contact tracers.

Investigator: Alexa Freglette

Contact Information: afreglette@wpi.edu

Introduction: You are being asked to participate in a research study. Before you agree, however, you must be fully informed about the purpose of the study, the procedures to be followed, and any benefits, risks, or discomfort that you may experience as a result of your participation.

Procedures to be followed: You will take part in a survey that will take approximately 5 minutes. This survey will be used to gauge the public's feeling towards the contact tracing during the COVID-19 pandemic, factors contributing to these feelings, and how, if possible, to improve upon forms of contact tracing. The survey will not include any data that is personally identifiable and will be deleted once analyzed.

Risks to study participants: There are no foreseeable risks, if in the event a participant feels uncomfortable and wants to leave, they can do so.

Benefits to research participants and others: The benefit of this research project will be a better understanding of the differences between manual and digital contact tracing. It is the goal of this project for it to be presented to National Health Organizations and spark conversation. This will force public officials to revisit their current tracing methods, recognize their pitfalls, and acknowledge areas where they can be improved upon.

Record keeping and confidentiality: As soon as the data is no longer necessary, it will be deleted. By the end of the project, all data will be deleted. Records of the participation in this study will be held confidential so far as permitted by law. However, the study investigators, the sponsor, or its designee, and, under certain circumstances, the Worcester Polytechnic Institute Institutional Review Board (WPI IRB) will be able to inspect and have access to confidential data that identify participants by name. Any publication or presentation of the data will not identify you.

Compensation or treatment in the event of injury: The research conducted by this project will not result in any physical harm or event of injury. You do not give up any of your legal rights by signing this statement.

For more information about this research or about the rights of research participants, or in case of

research-related injury, contact:
Researchers: Alexa Freglette, Tel. 347 804-3334, Email afreglette@wpi.edu
PI/Faculty Advisor: Kevin Lewis, Email: kmlewis@wpi.edu
IRB Manager: Ruth McKeogh, Tel. 508 831- 6699, Email irb@wpi.edu
Human Protection Administrator: Gabriel Johnson, Tel. 508-831-4989, Email gjohnson@wpi.edu.

Your participation in this research is **voluntary**. Your refusal to participate will not result in any penalty to you or any loss of benefits to which you may otherwise be entitled. **You may decide to stop participating in the research at any time without penalty or loss of other benefits.** The project investigators retain the right to cancel or postpone the experimental procedures at any time they see fit.

By signing below, you acknowledge that you have been informed about and consent to be a participant in the study described above. Make sure that your questions are answered to your satisfaction before signing.

To consent to this agreement, please type your name below.

_____

IRB Approved Survey Questions

[Will appear if consent form above is signed]

Do you believe that COVID-19 has negatively impacted your life?

- ○ Yes
- ○ No

Do you believe that COVID-19 has negatively impacted your life?
If the participant would like to elaborate, a short answer response

_____

Do you believe a stigma exists around the COVID-19 pandemic?

- ○ Definitely not
- ○ Probably not
- ○ Might or might not
- ○ Probably yes
- ○ Definitely yes

Do you believe a stigma exists around the COVID-19 pandemic?
If participant would like to elaborate, short answer response

_____

Have you contracted COVID-19?

- ○ Yes
- ○ No
- ○ I do not wish to respond.

[Will appear if above is answered "Yes"]

Were you contacted by a manual contact tracer when you contracted COVID-19?

- ○ Yes
- ○ No
- ○ I do not wish to respond.

Did this contact happen in a timely manner?

- ○ Yes
- ○ No
- ○ I do not wish to respond.

Did the contact tracer offer helpful resources?

- ○ Yes
- ○ No
- ○ I do not wish to respond.

Did you find this interaction helpful?

- ○ Yes
- ○ No
- ○ I do not wish to respond.

Do you believe that this interaction could have been improved?

- ○ Yes
- ○ No
- ○ I do not wish to respond.

Do you believe that this interaction could have been improved?

If participant would like to elaborate, short answer response.

_____

Do you currently use / have you previously used a digital contact tracer, or an application that tracks GPS or Bluetooth data to track if you have encountered someone who has contracted COVID-19?

- ○ Yes
- ○ No
- ○ I do not wish to respond.

[Will appear if above is answered "No"]

Is a reason you have not used this form of contact tracing because you are unaware it exists?

- ○ Yes
- ○ No
- ○ I do not wish to respond.

Is a reason you have not used this form of contact tracing because you are unaware it exists?

If not, what can digital contact tracers improve upon?

_____

If participant would like to elaborate, short answer response

_____

Is the reason you have not used this form of contact tracing because you are anxious about the data it collects?

- ○ Yes
- ○ No
- ○ I do not wish to respond.

Among the reasons you did not use a digital contact tracer, is privacy one of these reasons?

- ○ Yes
- ○ No
- ○ I prefer not to answer.

Are there other reasons you have not used digital contact tracers?

- ○ Yes
- ○ No
- ○ I prefer not to answer.

Are there other reasons you have not used digital contact tracers?
If participant would like to elaborate, short answer response

_____

IRB Approved Interview Questions

Please confirm that you have signed the IRB contract.

1. How has the COVID-19 pandemic impacted your life?
2. Do you believe a stigma exists around the COVID-19 pandemic? Why, what is that stigma?
3. Have you contracted COVID-19?
    a. If yes, were you contacted by a manual contact tracer when you contracted COVID-19?

A digital contact tracing application is one that tracks phone's via GPS or Bluetooth data to notify if you've encountered someone who has contracted COVID-19

Do you know what a digital contact tracer is?

4. What are your thoughts on digital contact tracer?
    a. Have you ever used a digital contact tracer?
        i. If yes, what are your thoughts on the applications
        ii. If not, why not?
    b. What would need to be done to make you want to use a digital contact tracer?
5. How would you feel if it was required by your country to use a digital contact tracer?

Interview 1

Interviewer

Please confirm that you have signed the IRB contract

Participant

I have.

Interviewer

So how has COVID-19 Pandemic impacted your life?

Participant

It's forced me to go remote for my job working at the house. I was unable to see my family and friends for a long period of time and it was impactful on getting essentials for my family, food and other things.

Interviewer

Do you believe that there is a stigma that exists around the COVID-19 Pandemic?

Participant

Yes. That it's easily contracted. If you come in contact with it, it's highly contagious and it's deadly.

Interviewer

So have you contracted COVID-19 previously?

Participant

No.

Interviewer

A Digital contact tracing application is one that tracks a phone via GPS or Bluetooth data to notify that you've encountered someone that has contracted COVID- 19. Have you heard of this term before?

Participant

Yes.

Interviewer

And what are your thoughts on digital contact tracing?

Participant

I don't agree with it. I think it's highly invasive and it's an invasion of Privacy.

Interviewer

Have you ever used digital contact tracer?

Participant

No.

Interviewer

If you were to go about using one, if it was required, what updates would need to be made to make you feel safe about the application.

Participant

It has to be anonymous and able to guarantee not getting to any of my data. It would be only used to track this and the data would not be shared with anybody, any other Department, or any other outside firms.

Interviewer

How would you feel if your country decided that we're required to have digital contact tracing?

Participant

I think that would be an invasion of my Privacy and I would be upset about it.

Interviewer

Thank you.

Interview 2

Interviewer

So please confirm that you have signed the IRB contract.

Participant

Yes, I did.

Interviewer

How has the COVID-19 pandemic impacted your life?

Participant

Im a teacher, so in New York state, we were half the time remote and half time in person. I do work for a special education. So district 75 pushed for the children to be in person. Uh, some staff was able to work fully remote and there was a lot of controversy with that.

Interviewer

Do you believe a stigma exists around the pandemic?

Participant

Yes. There was a lot of anxiety because of it. The stigma people were afraid, so they were blaming, you went to parties. We were staying home.

Interviewer

Did you contract to COVID-19?

Participant

I have not. So I took a lot of precautions to stay healthy, wearing my masks, stayed away from. people.

Interviewer

Digital contact tracing application is one that tracks your phone via trucks, your phone for your GPS or Bluetooth data to notify. If you've encountered someone who has contracted COVID-19, what are your thoughts on digital contact tracing?

Participant

Well, I signed up to be known. I signed up for the notification in New York and New Jersey. That's the places where I basically am. So I am for digital contract contact tracing.

Interviewer

Why is this?

Participant

I'd like to know what's happening so I could protect myself, protect my family, my coworkers, the elderly, and our children.

Interviewer

How would you feel if it was required by your country to use a digital contact.

Participant

Maybe I wouldn't feel as strongly about it. If it was mandatory, just like the vaccination, the mandatory vaccinations that are being instated. I am vaccinated.

Interviewer

What do you think would need to be done to make other people more comfortable with this digital contact tracing?

Participant

Assure them that their personal information won't be compromised and sent to any other establishments. Oh, okay. Thank you.

Interview 3

Interviewer

Please confirm that you have signed the IRB contract.

Participant

Yes, I have.

Interviewer

How was the COVID 19 pandemic impacted your life?

Participant

It was nice at first, I had a lot of time just like to myself. So, I think there was a period of self-growth, which was nice. But then, as time went on, it got more frustrating that I couldn't do the things that I enjoy. I just wished after like a certain point we were able to get on with our lives and now it's at a point where everything that you do in your life revolves around [COVID], which is stressful and frustrating. I just try to live my life the best that I can and not let other outside distractions impact me that much.

Interviewer

Do you believe a stigma exists around the COVID-19 pandemic?

Participant

What do you mean by stigma?

Interviewer

Such as finger-pointing and pointing blaming other people.

Participant

Yeah. Yeah, I do. It's like we're in this and no matter how much people want to point the finger or play the blame game, it doesn't really change anything. For example, in politics, people just like to blame the other, it’s just annoying because it's neither side really. Like when Trump was president, everyone was like, oh, he handled this so terribly, it's awful. Now that Biden's president COVID still going on. He’s the one who promised to get it under control and it does not seem like we have it under control. It’s just like one group pointing fingers at another. If we just work together, I feel like it'd be a lot easier to get to a better place. But there sure is a lot of blame to be put around.

Interviewer

Have you contracted? COVID-19.

Participant

Not to my knowledge, but like I, maybe I did.

Interviewer

A digital contact tracing application is one that tracks a phone GPS or Bluetooth data to notify you. If you've encountered someone who has contracted COVID-19, did you previously know the definition of a digital contact tracer?

Participant

No.

Interviewer

What are your thoughts on digital contact tracing?

Participant

Seems like a little much.

Interviewer

Please elaborate.

Participant

I mean like what would a device like this or service entail?

Interviewer

Usually, you would sign up for an application to see your GPS and Bluetooth data. If you have come in contact with someone, for example, on a bus or in a restaurant that has contracted COVID, they would be able to be notified, which contrasts with manual contact tracing, where you can like it's just based on the person's memory. So, people are offering digital contract tracing to inform those you might not know that you've come in contact with.

Participant

I think it has like good intention and like a good application. I see the positives for it, but also I think like it's again kind a little much like I go like to a bunch of different places during my day. The athletic facility, I go to the dining hall I walked through town, and I encounter a lot of people in my day to day, so I feel like it's very likely that somebody, I may have bumped paths with maybe had the virus or will contract in. It might end up being like every day. Would you need to know if this person that you were near contracted COVID and be told you should get tested? If it were someone that I was hanging out with. I would want to know if there were sick, and if they were I would get a COVID test. I see the good intentions for it and its applications, but I think that might just be a little too much.

Interviewer

So have you used a digital contact tracer?

Participant

Have I used one? No, I have not.

Interviewer

What would need to be done to make you want to use a digital contact tracer. For example, what features would you want to see to make it more impactful for you as a user?

Participant

I don't know. I guess as I said before, if it's just somebody I may have bumped paths with and I didn't really spend a lot of time for example, a stranger I walked past during the day I don't feel like that's necessary to be like information. I don't think that I'm going to get COVID from that. But like, if it's like a person who may be like, I sat down with having a conversation with spent a prolonged period in close proximity to, I think that would be like a good thing to notify. If it's every person who I come close to that is just going to give me a notification. That's like almost every day.

Interviewer

Just as a point of information, most applications attempt to take into account the six feet, 15 minute rule. However, most struggle with accuracy.

Participant

Okay. That would just be a concern that I would have.

Interviewer

And then last question how would you feel if it was required by your country to use a digital contact tracer?

Participant

I wouldn't like that. It's like forced. That's insanity. I think that's an overreach of government power. I think it's unconstitutional. I don't think that our country would get with it as right now. A lot of vaccine mandates are being pulled back because they're being blocked by federal judges on grounds of unconstitutionality. I don't think that the public would be like the consensus of people would be in favor of that as a mandate. I think it's a nice option to give people who are more concerned about contracting the virus and you know about their health and wellbeing, but to make like every US citizen to have to carry some device or register for something; I don't think that's a good idea. I don't think the public will react very kindly to that idea either.

Interview 4

Interviewer

Please confirm that you have signed the IRB contract

Participant

Yes, I have.

Interviewer

How has the Covid-19 Pandemic impacted your life?

Participant

I think the Covid-19 has impacted my life by making it more difficult to go out and do day-to-day activities. But I think that it is not just for me, but for everybody.

Interviewer

Do you believe a stigma exists around the COVID-19 Pandemic?

Participant

Yes, 100%.

Interviewer

Why do you think this stigma has occurred and what is this stigma?

Participant

I think it has changed over time. So, I have had COVID-19 twice so far, in March 2020 when it was new and then again three weeks ago. I think I have seen a change in the way people react when you tell them you have COVID. But I think also there is a stigma around it. When I first had COVID everyone around me treated me like I was going to die, including the government. I called the hotline because back then we didn't know what to do. I was quarantined at home with my parents who were immunocompromised, and I wanted to make sure I wasn't going to kill my parents being home with them. When I called the hotline they said, "You're young you should live." This is the direction of the government. This is not acceptable. When I told everyone that I had Covid no one wanted you to be near them, no one wanted to see you, no one wanted to talk to you, and even now I contracted it almost two years later and was out of my office for three weeks. I needed to be completely symptom-free before I could return to the office. This is good to keep everyone safe, but bad because things get backed up and it's very disruptive to life and work. If I was only sick for one week, why do I need to be out for three? I think there is an overabundance of caution. Even with my return to the office, I need to keep my door closed and wear a mask. No one wants me to sit with them at lunch, a little bit of a stigma, I think. People think that you're disgusting, and no one wants you near them, because they're afraid of getting sick.

I think everyone will either get it or have it. My fiancée didn't have symptoms in March 2020, but when we went for antibody testing before going back to work, he had the antibodies. Now, my friends went to dinner and three days later three of us tested positive and my fiancée again tested negative.

Interviewer

Since you have contracted COVID-19, were you ever contacted by manual contact tracers?

Participant

The first time I was not, however the second time I was.

Interviewer

How was that experience?

Participant

They were nice, I got tested on December 17th, but didn't hear back from the contact tracer until the 23rd of December. It was almost a whole week later. My brother who was tested on the same day heard from them the next day. I think it was slightly inconsistent. They called and said, "Just so you know you tested positive for COVID-19 last week." Thankfully I knew, but if I didn't get my results and was waiting on this call I would have been out for a whole week and infecting people. But otherwise, they were very nice and thorough. They provided different phone numbers I can call in case I had questions or if I needed a letter to return to work. I think they were helpful and checked in, but there needs to be more consistency in the time of contacting people.

Interviewer

A digital contact tracing application is one that tracks a phone's location via GPS or Bluetooth data to notify if you have encountered someone who has contracted COVID-19.

Did you previously know the definition of a digital contact tracer? Have you heard of it before?

Participant

I have heard of the apps. I think there's an NYSCovid that is supposed to tell you if someone has encountered COVID-19. I also think Apple has a built-in COVID tracker now. I've never been alerted on either of these applications and obviously, I have met those infected with COVID-19. I have heard of it; I don't know how they necessarily work. But if that's the case I don't think they work because I have two and neither one of them had informed me of my encounters with COVID-19.

Interviewer

So, you are using or think you are using a digital contact tracing application. What would need to be done to make you want to use it more frequently?

Participant

One would be being more accurate. I think I would also want the application to run in the background. I don't want to have to check in and see if there is COVID at this restaurant. I would rather it ping and use other people's geolocation to see if someone in a restaurant was exposed to COVID and warn users to wear a mask. I think it should do it automatically and run in the background. There could be ethical concerns with this, such as privacy with applications like this. However, this would be more useful than having to search the application. I would prefer if it would automatically track to be useful on a wide scale.

Interviewer

The intention of most digital contact tracing applications is supposed to work in the background. I am not too sure about those applications but theoretically, they should be notifying you after you have met an individual that contracted covid contact and warns you that you are a close contact. The idea of them is your phone and another phone has come in contact and a few days later if that person tested positive your phone would be notified because you were in proximity to each other.

Participant

I think that would be useful.

Interviewer

Some countries are currently requiring people to download a digital contact tracer to track their location and see if they are meeting other people. How would you feel if the US began to enforce this?

Participant

I think that would infringe on people's right to privacy but not to be the lawyer but maybe it infringes on people's free travel interstate travel--it might be a constitutional issue. But if it is for the public's safety and mass public welfare it might be a good idea. I don't think I would necessarily; like to be tracked but if they are just using it for public health data, with the right safeguards I think it could be beneficial.

Interviewer

I appreciate you joining me today, thank you for participating in my interview.

Interview 5

Interviewer

Please confirm that you have signed the IRB Contract.

Participant

Yes, I have.

Interviewer

How has the covid 19 pandemic impacted your life?

Participant

It's impacted my life through my work and my home. I am a nurse so of course working different shifts, working with a different population of patients that are not my specialty because I was pulled because we had such a staffing shortage. Educating patients educating staff members. learning more, it was kind of a trial-and-error process. Definitely redefines what your necessities are, especially at work. We went from having things that were available t having two pairs of gloves and one N-95 mask. Deciding what patients need and which don't. Remember how to garb up in gull isolation gear which involves the face shields, the smock, gown, gloves, and double masking. Then the cases went down, and we began to let our guards down a little bit because it started to trend down. Then boom it went back up again so we had to be on our A-Game. Home, Keeping my family safe from whatever I was bringing in. There were times I would have to take off most of my clothing in the driveway before I would even walk in the door because I was petrified of what I would expose my family. Keeping my family members safe. Also, there was a supply and demand issue. I was afraid my family would run out of toilet paper and paper towels. You couldn't even get Lysol which I feel that almost everyone experienced.

Interviewer

My second question is do you believe there is a stigma existing around the COVID-19 pandemic? What is that stigma?

Participant

There is definitely a stigma. Other than the Baby Boomers that did deal with some stuff way back when none of us have ever been exposed to anything like this prior. We had no idea of how to interact with people and how to deal with this as a community. It became very man-vs-man. You didn't want to go out or be anywhere. You didn't want a person within six or twenty feet near you. It was similar to isolation stigma, where I feel like society became agoraphobic, society became afraid of everyone, and everyone was the enemy. It was definitely very political, no matter which side you were on it was the other side's forth. There was a political stigma, and socially there was isolation keep to your own and stay away because everyone else is infected.

Interviewer

Next question, have you contracted COVID-19?

Participant

No, I have not. I have been ridiculously exposed, both professionally and personally and I have never contracted it.

Interviewer

What are your thoughts on manual contact tracing?

Participant

I have experience with it both professionally and personally. Professionally, in the beginning, prior to what we now know as contact tracing, we had a patient that came in that was symptomatic. We had to figure out who they were with when was the last time they were at the office, asked for a list of who was possibly exposed. Then, when the patients would come in to deliver or any type of hospital experience, we would have to test them. If they came up positive, we would have to trace back and come up with a person who most definitely was negative to release the newborn babies to. This became very scary, traumatic, and stressful to everyone involved.

I also dealt with it personally when my sons contracted COVID-19, which was worse than dealing with it professionally because the questions every day are crazy. It is a labor-intensive process on the contact tracer's end and I don't know if it is as beneficial as they would have hoped it to be. I don't know if it significantly impacted the reduction of transmission of COVID.

Interviewer

My next question involves digital contact tracing. A digital contact tracing application tracks a phone's location via GPS or Bluetooth data to notify if a person has come in contact with a person who has contracted COVID-19. Have you previously heard of this term?

Participant

We used the app when everyone here either had it. My son had been signed up a few times at school when he was in a classroom and exposed. That was through the New York City Department of Health which had to answer many questions instead of manual contact tracing. I haven't had to deal with that aspect of it professionally. I see in theory how it could work. If we went back to the beginning of who came from where and where they traveled to. It is interesting to watch the disease spread. I know the theory is to almost get ahead of the virus, but I don't think no matter how quickly we can get on top of it, it won't do much to stop the impact of it. Viruses are very smart and adapt much quicker than we do. They will always be 10 steps ahead of us, take the common cold for example. We will never find a cure for it, but at some point, our bodies become strong enough to function with it. I think this is what will happen with COVID-19.

Interviewer

What would need to be done to make you want to use a digital contact tracer or make you feel safe using a digital contact tracer?

Participant

I would use it, absolutely if it will impact society. I am not opposed to it, but I think until we can figure out how to pinpoint where the next steps of the virus are we will always be behind the virus. You can gather a lot of data from being in this position too, but I don't know how we could use this data in a preventative state other than completely isolating someone that has the virus.

However, we change that rule very often. Even when we tried shutting down it still didn't do much. I don't think digital contact tracing will be preventative but rather used for the collection of data. Perhaps used to understand where our hotspots are and see how to space people out. In cities, everyone is on top of each other, compared to rural areas where people have a lot more space.

Interviewer

Final question, how would you feel if it were required by your country to use digital contact tracers?

Participant

I believe this is currently occurring, or at least a similar concept is being explored in Hong Kong. I have a cousin there and the isolation procedure is very intense. I do not think something like this would work in the US. I feel like the US is a very different country than twenty years ago. If people want to participate in something like this that's great, however, I don't think that a person should be forced to do so, even with all of that. My cousin lives in Hong Kong, and I witnessed the process when he tried to come to the US. It was like three weeks of isolation before you can leave, and then three weeks of isolation before you can come back and be integrated into society again. The three weeks are spent in a COVID hotel on your own dollar. I don't think something like that would work here. Once it's forced, I am opposed to it because it does impact your freedoms. I don't think the government should know where you are always, no one should know.

Interviewer

Thank you for your participation in my interview. I appreciate your responses.