Utilizing QR Codes for Public Health Contact Tracing in Low-Resource Communities

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Abstract

UPTrace is a browser and Android contact tracing application (CTA) for low-resource communities. This CTA identifies locations through QR codes and has separate interfaces for general users and contact tracers. It was designed to address privacy and usability issues that are present in currently available local and global CTAs.

Results of user tests indicate that 87.5% of general users and 25% of contact tracers will likely use UPTrace and recommend it to others. The remaining respondents indicated that they will likely use UPTrace but would only recommend it after some improvements.

1 INTRODUCTION

An effective contact tracing methodology could help reduce the spread of viruses like coronavirus disease (COVID-19). Contact tracing was traditionally done manually by interviewing infected persons and identifying their close contacts. Such manual contact tracing has been proven to be effective in controlling the spread of Ebola between 2014 and 2016 [19]. However, manual contact tracing largely depends on an individual's ability to recall who they were in contact with whom they might not even know personally. To overcome this limitation, the use of digital contact tracing through CTAs could be a better option given that digital contact tracing has a high adoption rate and will be followed up by testing and isolation. CTAs can provide more accurate data and can lessen virus transmission because there is no need to use pen and paper in filling out manual contact tracing forms anymore. Given the various CTAs available, and given that each of them has its advantages and disadvantages, this research aims to compare and contrast the underlying technologies used in international and local CTAs. Their design will be considered in developing an exclusive CTA for a low-resource community.

The proposed app aims to improve the existing contact tracing process in low-resource communities by addressing the issues that the community contact tracers face. These issues were identified by reviewing the official documents related to the COVID-19 pandemic in the target community's website [25, 31] and by conducting an interview with the community contact tracers.

The proposed app's usability was also evaluated through remote user testing due to the physical limitations under the COVID-19 pandemic.

2 REVIEW OF RELATED LITERATURE

2.1 Difficulties in Manual Contact Tracing

Manual contact tracing can be problematic because it requires more time to process. Aside from this, it is prone to human error which heavily affects the accuracy of the entire process. Sometimes, contact lists are lost, inadequate data are collected, and there are errors in transcription of data. Lastly, it requires a huge amount of effort from data collection to data analysis. Attempts to address these problems, such as the study of Sacks et al. and Danquah et al. [26, 12], both resort to the transition to digital contact tracing through mobile apps.

In the Philippines, there have been numerous accounts of personal information falsification in contact tracing documents [18, 14]. Because of situations like these, contact tracing may take a longer time and close contacts may not be identified. Manual contact tracing can also be inconvenient and time-consuming because it requires people to write too much information such as address, phone number and visited places, and doing so raises privacy concerns [15].

2.2 Existing Technologies used in CTAs

Fortunately, through technology, various CTAs for COVID-19 have emerged. These CTAs use widely known technologies specifically (1) Bluetooth, (2) Global Positioning System (GPS), and (3) Quick Response (QR) Codes.

Bluetooth technology is susceptible to sniffing, bugging, and jamming because of its vulnerable wireless interface [32]. It relies on the strength of signals received from other phones, which may be inaccurate, since signal strength is affected not only by proximity, but also by obstacles between phones [30]. Moreover, using Bluetooth technologies drains battery, cannot provide relevant patient and location information in exchange of anonymity, and can be intercepted and used for malicious purposes [17, 16].

On the other hand, CTAs that use GPS identify close contact users through their geographic location and time information. A downside of this method is accuracy, especially in indoor locations. For example, if two users are in the same building, with the same x and y coordinates, but are in different levels (z coordinate), GPS technology will identify them to be in the same exact place. Not only that, it also basically tracks its users which raises a privacy concern and has an issue with battery consumption [30].

Lastly, CTAs that use QR codes offer high accuracy from the information embedded on the QR codes about an establishment or a user assuming that true information are provided. In integrating QR codes, it can either be the user scans the QR code of the establishment they are visiting or vice versa [21]. QR codes being accurate, however, raises privacy issues because the data stored in the database are raw and include relevant information about the users which may be used to identify them.

A summary of existing technologies used in CTAs is provided by **Table 1**.

2.3 Existing International CTAs and Local CTAs

Many CTAs have been built and released since 2020 to augment the pandemic response of many countries. In this section, two international and two local CTAs will be analyzed.

Starting with international CTAs, Aarogya Setu is the main CTA used in India, made by India's National Informatics Centre. When users register, they need to provide their name, phone number, age, gender, profession, and list of countries visited in the last 30 days. The app uses a combination of Bluetooth and GPS to identify Bluetooth contacts of infected users for the past 14 days and potential hotspots of COVID-19. As of date, its required minimum Android version is 5.0 and its required minimum iOS version is 13.5 [5, 6].

On the other hand, Zwaai.app is a proposed CTA that was developed by a group of researchers in Radboud University in the Netherlands. The developers decided to use QR codes for this app to ensure accuracy and to avoid privacy issues that come with using Bluetooth which is commonly used in other CTAs. Scanning a QR code generates a random number which is used to identify close contacts anonymously.

For local CTAs, StaySafe PH is the official contact tracing system of the Philippine government. It uses Google Apple Exposure Notification (GAEN), a Bluetooth technology supported by Google and Apple [29, 24]. GAEN is used in their mobile app while QR codes are used in the browser app whose purpose is for logging in establishments and scanning individuals they were in contact with. In the mobile app, only the positive case number is required while for the browser app, sensitive information such as name, phone number, birth date, gender, and complete address are required. As of date, its mobile app's required minimum Android version is 6.0 and its required minimum iOS version is 13.5 [9, 10].

Lastly, Traze is a CTA launched by the Philippine Ports Authority and is mainly used by Philippine port passengers and terminals [23]. It uses two-way QR code scanning to scan and trace individuals and establishments. As of date, its required minimum Android version is 4.4 and its required minimum iOS version is 13.0 [11, 1]. Traze can work offline and with slow data and WiFi. Username, password, name, phone number, email address, profile picture, and town/city of residence are required from users.

Table 2 shows a summary of the comparison of the mentioned international and local CTAs.

2.4 Privacy Issues on CTAs

In the study of Cho et al., there are three desirable notions of privacy defined in the context of creating a CTA that utilizes Bluetooth technology and tokens—privacy from snoopers, privacy from contacts, and privacy from the authorities [7]. Privacy from snoopers is a protection against users that capture data among users without authorization by sniffing or eavesdropping. On the other hand, privacy from contacts states that information of a user should not be accessible to their close contacts. Lastly, privacy from the authorities signifies protection from whoever is administering the app. [2]

2.5 Usability Evaluation for Mobile Apps and Digital Contact Tracing

User adoption rate and continuous app usage are essential factors for a CTA to be effective. This can however be impeded if the CTA is not highly usable [27].

	Bluetooth	GPS	QR Codes
Mode of Use	Requires app to run in the background (and in the foreground on iOS devices); requires Bluetooth to be on (which is battery-draining)	Requires app to run in the background; requires GPS tracker to be on (which is battery-draining)	Requires app to run every time a QR code is scanned
Accuracy	Low accuracy especially if there are obstacles between phones	Low accuracy if inside indoor locations	High accuracy if users provide factual information and constantly scan QR codes
Privacy	Privacy-preserving solution (provides anonymity)	Privacy concerns on location tracking	Privacy concerns on database security

Table 1. Summary of Existing Technologies Used in Contact Tracing Applications

ISO 92411-11 is an international standard that defines usability in terms of effectiveness, efficiency, and satisfaction [3]. These properties can vary depending on the context of the product being developed. In the context of digital contact tracing systems, a paper by Trivedi and Vasisht [30] defined the following metrics for measuring effectiveness:

1. Accuracy - A digital CTA should not have many false positives (people falsely identified as possible close contacts) and false negatives (unidentified people who were actually in contact with a positive patient).
2. Privacy, Data Security, and Ease of Attacks - The amount and type of data collected should only be what is necessary for a CTA to work properly. To encourage more people to use a CTA, they should also be assured that the sensitive health and location information they share are protected and not compromised or leaked.
3. Ubiquity - To make large-scale app adoption possible, a CTA should be compatible with smartphones using outdated software and scalable enough to handle large traffic while still providing accurate data.

System Usability Scale (SUS) is a tool in measuring the perceived usability of an app [20]. SUS is a 10-item Likert scale that provides a global view of subjective assessments of usability of an app [4]. In the study of Scherr et al. [27], where they developed a CTA called MyCOVIDKey, SUS was used to test its usability. The Likert Scale used has 5 options varying from strongly disagree to strongly agree. They also recorded the time it took for users to complete a specific task and found out that it was short. In their study, only 30 out of 45 testers provided feedback through a survey. The researchers concluded that MyCOVIDKey is usable because it had a score of 70 on the SUS, which is above 68 - the accepted threshold for usability. Aside from the Likert scale, the researchers also collected user demographics such as gender, age, race, and occupation.

3 METHODOLOGY

This study aims to create a CTA that not only considers existing protocols and technologies for low-resource communities, but also has a high usability. Usability is evaluated using survey questions based from SUS which uses the Likert scale.

3.1 Requirements Gathering

The University of the Philippines (UP) Diliman community was selected as a case study in order to examine the feasibility of the proposed CTA. This low-resource community has a population of over 40,000. But its primary care facility serves not just the students but also university employees and other campus residents comprising of at least 15,500 informal settlement households. The University Health Service (UHS) is the primary care facility that employs the community contact tracers. Current contact tracing protocols in the UP Diliman community involves a Health Liaison Officer in each office/unit who are expected to report daily to the UHS Public Health Unit regarding the situation of their office/unit regardless if there is a patient that discloses to be positive or suspected [25, 31].

The researchers conducted an interview with the community contact tracers regarding the possible design of the CTA. During the interview, the contact tracers named some difficulties that they are experiencing with their current protocols. However, because of time constraints, this study will only address a subset from this set of difficulties. This subset is composed of:

CTA	Aarogya Setu	Zwaai.app	StaySafe PH	Traze
Country that Developed the App	India	Netherlands	Philippines	Philippines
Technology Used	Bluetooth and GPS	QR codes	Bluetooth and GAEN for mobile app, QR codes for browser app	QR codes
Minimum Required OS	Android: 5.0 iOS: 10.3	Not applicable	Android: 6.0 iOS: 13.5	Android: 4.4 iOS: 13.0
Purpose	Notify exposed close contacts identify potential hotspots, and display COVID-19 vaccination status	Notify exposed close contacts	Notify exposed close contacts and provide scanning history	Provide scanning history
Required Information	Name, phone number, age, gender, profession, and list of countries visited in the last 30 days	None	Name, phone number, birth date, gender, region, province, municipality, barangay	Username, password, name, phone number, email address, profile picture, town/city of residence
Required Users to Install the App	Individuals	Individuals	Both individuals and establishments	Both individuals and establishments
Data Retention Period	30 days for non-infected users in a mobile phone's local storage and 60 days for infected users in app's server	Not stated	30 days	30 days
Works Offline	Yes, but only for scanning nearby devices	Unclear	No	Yes, but only for scanning QR codes
Provides COVID-19 Statistics	Yes	No	Yes	No
Provides COVID-19 Information or Precautions	Yes	No	Yes	No

Table 2. Comparison of International and Local CTAs

1. The memory of the patients regarding their whereabouts and close contacts is unreliable.
2. Delays in the Health Liaison Officer daily report heavily affects the contact tracing.
3. The preference of patients regarding the time that the contact tracers get in touch with them varies. Thus, the contact tracers suggested associating this information with the users.
4. During interviews, some patients prefer that contact tracers ask all questions at one time while some patients prefer one question at a time.

3.2 Proposed Design

From the review of existing technologies and CTAs, and based on the interview with the target contact tracers, the researchers have decided to develop a CTA that (1) offers some level of accuracy and security, (2) addresses issues on privacy, and (3) is usable. For these reasons, the CTA that was developed is a QR code-based CTA that runs under the HTTPS protocol and is available in both browser and mobile platforms. It is designed to have a centralized database with only the developers and the contact tracers as administrators. Having

a centralized system is the only way of administering diagnoses properly [33] because it allows health authorities to easily access patient information. The study of Nakamoto et al. [22] also mentioned that a centralized database that accommodates infected patients addresses the reliability of the contact tracing system.

3.3 Implementation

The browser app is built using Angular and Bootstrap 5 while the mobile app is built using React Native. The backend of both apps use NodeJS, Express, and MySQL. The browser app is deployed in Github Pages while the backend is deployed on Amazon Web Services. Since UPTrace is a prototype and not supported by any organization, the mobile app was not made available on iOS due to restrictions of App Store regarding CTAs. Fortunately, the researchers were able to initially deploy its Android version on Google Play Store but was eventually took down because of the same restrictions on CTAs [13, 8].

Both apps should function properly assuming that the community's internet provider can provide stable internet access.

There are three types of users in the app. First is the Health Liaison Officer who populates the database with rooms and entry points in the building of the office/unit they are assigned to. Next are the contact tracers who monitor patients and their close contacts. Lastly, all users (i.e. students, employees, and visitors) can scan QR codes upon entry of buildings and rooms.

Both apps have the following main functions and features which are summarized in **Table 3**:

- **Signup/login using using phone number** - Signup requires an OTP-verified phone number, password, preferred contact time, and preferred way of interview. OTP is provided by Semaphore [28]. Login only requires phone number and password. No other personal information is required from users to ensure that shared data cannot be traced back to an individual. This will address the privacy issues present in the reviewed CTAs which require data such as name, age, gender, and address.
- **Scan QR code** - This allows all users to log their entry in each building and room in the community at a specific time.
- **Disclose suspect or positive case** - This allows all users to disclose their condition.

The following features are exclusive to the browser app:

- **Signup/login using using phone number/Google account** - This is only available for Health Liaison Officers and contact tracers. A registered Google account is required in addition to above mentioned signup information. Login only requires phone number/Google account and password.
- **Add building and room** - This allows the Health Liaison Officers to add and generate downloadable QR codes of buildings, rooms, and entrances in the community that are not yet in the database.
- **View and filter patients** - This allows the contact tracers to see the list of disclosed suspect and positive cases and to update the status of each patient. They may filter patients by date and status (i.e. Suspected, Disclosed Positive, Confirmed Positive, Confirmed Negative). They may also filter out patients assigned to themselves.
- **View possible close contacts** - This allows the contact tracers to view and download the list of close contacts in an Excel workbook. They can also view each close contact's basic details aside from the type of exposure, and building, room and date of potential exposure. A possible close contact is defined as someone who:
  - Was in at least one same building or room on the same day with a symptomatic patient two days prior to the onset of symptoms until the patient's disclosure date; and
  - Was in at least one same building or room on the same day with an asymptomatic patient two days prior to the patient's disclosure date until the disclosure date.
- **View whereabouts** - This allows the target contact tracers to view and download, as an Excel workbook, the list of rooms and entry points entered:
  - By a symptomatic patient two days prior to the onset of symptoms until the patient's disclosure date; or
  - By an asymptomatic patient two days prior to the patient's disclosure date until the disclosure date.
- **Search patient by phone number and update health status** - This allows the contact tracers to search for a phone number so as to view patient details and update health status.

4 RESULTS AND ANALYSIS

The evaluation of the apps was done into two parts: (1) General Users Interface and (2) Contact Tracers Interface.

4.1 General Users Interface

Testing for the browser app and the Android app was done to evaluate the usability of both apps. Testing was done on dates April 5-21, 2022 among 16 respondents. Due to the pandemic, testing was done remotely. Testers must satisfy the following conditions:

All Users on Browser and Mobile App	Health Liaison Officer on Browser	Contact Tracers on Browser
Signup/Login Scan QR Code Disclose Status Check Health Status	Add Location Add QR Code	View and filter patients View close contacts and whereabouts Search users and update user status

Table 3. Summary of UPTrace's Functions and Features

1. Has a mobile phone with camera and sim card
2. Has a stable internet connection
3. Has a stable mobile signal
4. Has a timer (to be used in measuring the time taken in scanning a single QR code)
5. Has another device to display QR codes

The feedback of the respondents were gathered through Google Forms. The instructions for testing and the survey contents can be found at the appendix. First, information such as age, mobile service provider, and affiliation with the target community were asked from the respondents.

Next, the respondents answered survey questions using the Likert scale, with 5 as the highest (except for the question about impact which has 4 as the highest) and 1 as the lowest score, and with each score having a detailed description. Questions aim to evaluate the app's usability by using three metrics defined in ISO 92411-11L: effectiveness, efficiency, and satisfaction [3]. These metrics are defined as follow by the researchers for users:

1. Effectiveness - Ability to understand the app's purpose and how to navigate it
2. Efficiency - Ability to successfully scan a QR code in a short amount of time
3. Satisfaction - Reaction towards the app's privacy and willingness to use and recommend the app

Lastly, additional questions regarding preferred platform (Android or browser app), difficulties and issues encountered, and suggestions for improvements were answered by the respondents.

4.1.1 Demographics and Mobile Service Provider Testers' age ranged from 19 to 41. Out of 16 testers, 2 of them were 19 years old, 3 were 21 years old, 6 were 22 years old, and there was 1 tester for each of the following ages: 27, 30, 34, 37, and 42 years old. Age seems to have no effect on the intent to install and use the apps since 14 out of 16 testers expressed that they are likely to use and recommend the apps, as explained in section 4.1.7. Also, out of 16 respondents, 8 of them are affiliated with the community (2 alumni and 6 students) and the remaining 8 are not. Lastly, 8 testers use Globe as their mobile service provider, 5 use Sun, 2 use Smart, and 1 use GoMo. OTPs were successfully received in all mobile networks mentioned.

4.1.2 Understanding Concepts under understanding:

A. Purpose of the app
B. How to navigate the app
C. What will happen next after disclosing health status

Testers were asked about their understanding of UPTrace after testing. 93.75% of the testers said that they understood all concepts. Meanwhile, 6.25% of them said that he/she only understood concepts A and B. Overall, UPTrace is successful in being easily understandable because majority of them agreed that they have completely understood the app.

4.1.3 Functionality Functions relevant under functionality:

A. Signup/Login feature
B. QR scanning feature
C. Disclose health status feature

Testers were asked if both browser and Android apps work properly. As shown in Figure 2, for both apps, 93.75% of the testers said that all features are working properly. Also for both apps, 6.25% said that only the features A and B are working properly. It's the same tester that gave this rating for both apps because he/she thought that the Disclose button in the bottom part of the screen as shown in Figure 1, will show the forms needed in disclosing. However, this button is only used for navigating to the Disclose Page.

Although one tester misunderstood a button, overall, most features of UPTrace for both apps work properly as intended.

4.1.4 User Interaction Tasks assigned in user interaction:

A. Sign up/log in
B. Scan QR codes
C. Disclose health status

Testers were asked how easy or difficult it is to use both browser and Android apps. For the browser app, 87.5% of them answered that they find it easy to do all tasks as seen in Figure 3. Meanwhile, 6.25% answered

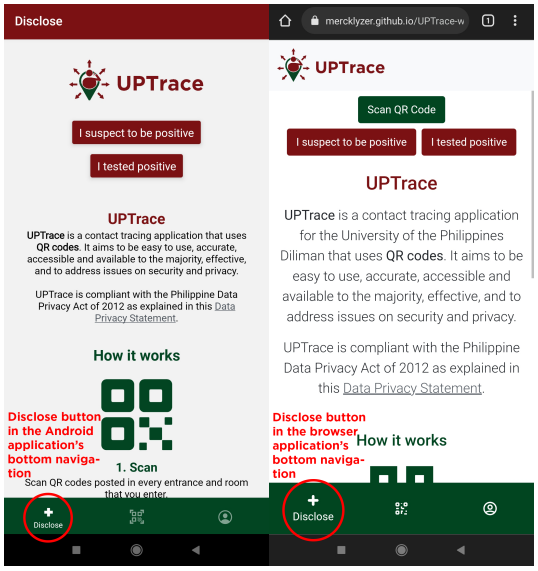

Figure 1. Disclose button in both applications

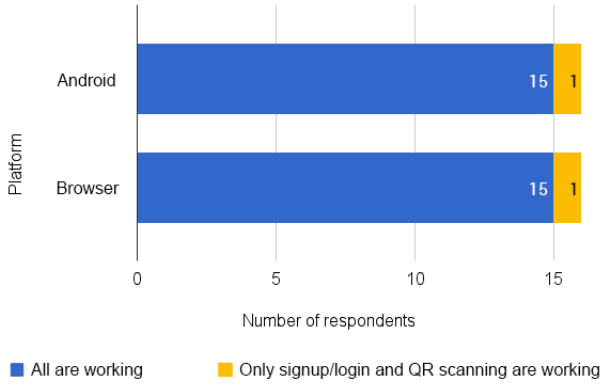

Figure 2. Features working properly in both applications

that it easy to do tasks A and C, but hard to do task B. Lastly, 6.25% that it is easy to do task A, but difficult to do tasks B and C. Some find it hard to scan in the browser app because the browser always asks for camera permissions. For the tester who finds it hard to disclose, the reason is that the buttons are close to each other in the browser app. In contrast, for the Android app, all testers said that they find it easy to do all tasks.

4.1.5 Time Consumed in Scanning To test if UPTrace is easy to use especially on its main feature - QR Code Scanning, testers are asked to record the time it took from the time that their phones are unlocked up to the time they have successfully scanned a single QR code. The responses are shown in Figure 4.

For the browser app, 81.25% answered that it only took them not more than 15 seconds to successfully scan a single QR code from the time that their phones are unlocked. 12.5% said that it took them not more than 30 seconds and 6.25% said that it took more than 30 seconds.

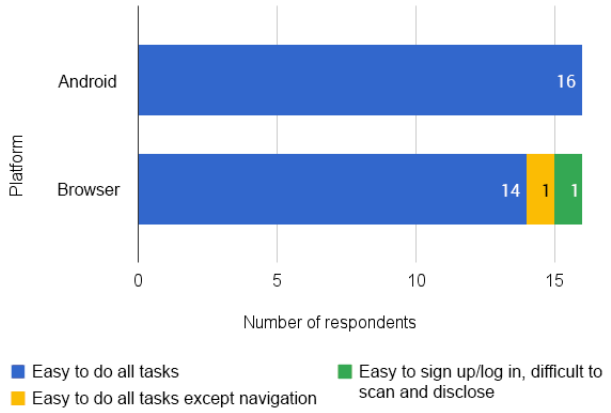

Figure 3. Ease of using both applications

For the Android app, 81.25% answered that it only took them not more than 15 seconds to successfully scan a single QR code from the time that their phones are unlocked. 6.25% said that it took not more than 25 seconds and 12.5% said that it took not more than 30 seconds.

Thus, scanning is fast for the majority of testers.

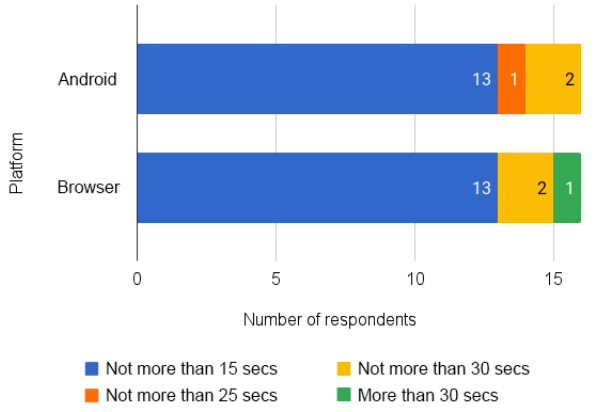

Figure 4. Time consumed in scanning

4.1.6 Privacy Testers were asked to rate how secure they feel in sharing their data in the apps. All agreed to share their data because the only sensitive data asked from them is their phone numbers. Although data about their whereabouts are also considered sensitive, there were no reported concerns about it. Thus, both apps were successful in presenting what data is needed from users and to whom these are shared. Testers feel secure in sharing their data because only the app developers and the contact tracers can access them, as explained in the Data Privacy Agreement that they have agreed with.

4.1.7 Impact Testers were asked how likely they are to use and recommend the apps supposing that the use of these apps will be recommended in the target community

and that they will visit this community. All testers are likely to use the apps consistently, but only 87.5% would recommend it to others. The remaining 12.5% would not recommend it because they are still seeking for more features to be implemented in the apps which will be discussed in the next section.

4.1.8 Additional Questions In this section, the testers were asked which app they tested first and which one they prefer and why. 50% of those affiliated with the target community and those who are not used the Android app first and the remaining 50% tested the browser app first. The type of app tested first did not seem to affect the testers' preference because the majority of them, 75% of the testers, preferred the Android app as reflected in Figure 5. 50% of these testers tested the Android app first while the remaining 50% tested the browser app first. Some reasons specified for their preference include, but not limited to, the following:

1. The Android app looks more credible because it was on Google Play Store.
2. The Android app scans more seamlessly because no camera app permission is constantly asked.
3. The Android app loads faster and it only takes one tap to open. Although the browser app can be bookmarked so that it would just require fewer taps to be opened, some users may not be aware of this.

On the other hand, 18.75% of the testers preferred the browser app because it does not have to be installed and thus saves storage space. Finally, the remaining 6.25% do not have a strong preference over the two apps for the reason that both apps work fine and having both of them is advantageous in case one of them hangs.

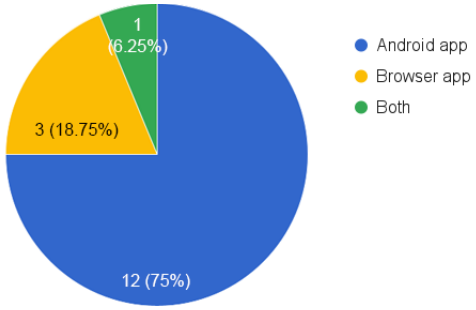

Figure 5. Preferred application

Some of the difficulties and issues the testers encountered include, but are not limited to:

1. Not all special characters are allowed in passwords.
2. The Data Privacy Agreement shows up even when a user enters a wrong OTP in the browser app.
3. The "Log In" button is not easily accessible in the Android app on smaller screens.

Finally, testers suggested some improvements which are as follows but not limited to:

1. Adjust range for selecting onset date depending on how long COVID-19 symptoms last
2. Enable profile editing and password resetting
3. Make user's logs visible to themselves

4.2 Contact Tracers Interface

The browser app for the contact tracers were demonstrated to them remotely through a Zoom Meeting. Afterwards, 4 contact tracers, whose ages are 32, 35, 35, and 56, gave their feedback through Google Forms.

4.2.1 Understanding Concepts under understanding:

A. Purpose of the app
B. How to navigate the app
C. What will happen next after assigning myself to a patient

As seen in Figure 6, 25% of the respondents completely understood all concepts. 50% understood concepts A and B. Lastly, the remaining 25% only understood concept B.

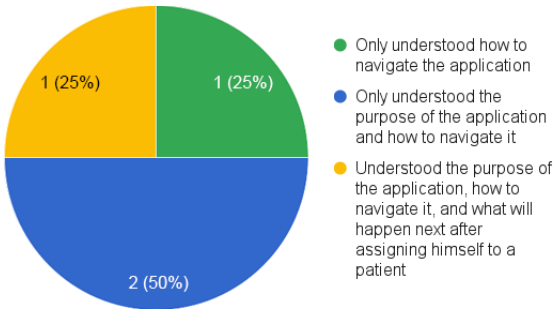

Figure 6. Understanding of the browser application

4.2.2 User Interaction Tasks assigned in user interaction:

A. Assign myself to a patient and update his status
B. View and download patient information
C. Search and filter patients

As shown in Figure 7, 25% of the respondents found it easy to do tasks A and B, but difficult to do task C. 50% found it easy to do tasks A and C, but difficult to do task B. Lastly, the remaining 25% found it difficult to do all of the tasks mentioned.

4.2.3 Impact As depicted in Figure 8, 25% of the respondents said that he/she is likely to recommend the app to be used by the target contact tracers as it is. The remaining 75% are likely to recommend it too, but after some modifications or improvements are made in the app.

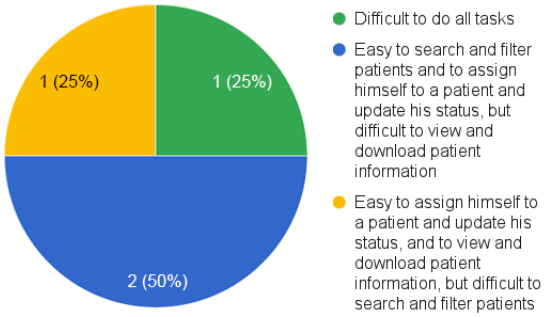

Figure 7. Ease of using the browser application

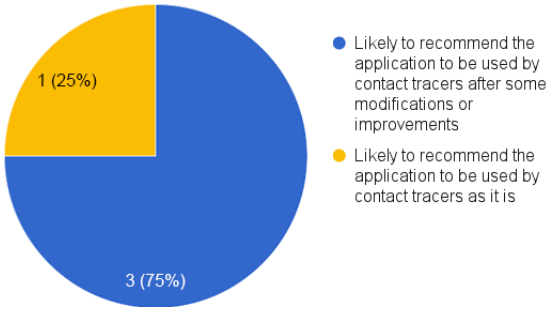

Figure 8. Likeliness to use the browser application

4.2.4 Additional Questions Although some respondents did not completely understand the features of the app and did not find it easy to use the app, there were no reported difficulties encountered. However, they suggested some improvements to be implemented which are:

1. Make the app more mobile-friendly
2. Require users to indicate their classification (i.e. UP employee, student, visitor, etc.) when signing up
3. Ensure that only the target contact tracers have access to the data, not even the developers

5 CONCLUSION

CTAs, when properly and constantly used, can help reduce the spread of COVID-19. By examining various CTAs, the researchers were able to determine the appropriate approach and technology to be used in developing UPTrace, a QR-code based CTA for a low-resource community. UPTrace is primarily composed of both general users and contact tracers interfaces wherein general users use their mobile phones to scan QR codes, and ideally, contact tracers use computers to analyze the data collected. It was fit into the context of the said community and was made while considering the needs of its contact tracers.

To evaluate UPTrace, testers were given instructions that served as their tour in using the app. And after finishing the tasks, they were asked to answer a survey. UPTrace's browser and Android apps for the general users interface were well-received as inferred from the survey. While both apps were easily understood, functioned enough to be useful, easy and efficient to use, and are recommendable, the Android app was preferred more by the users. Nonetheless, to further improve user experience, minor issues in both apps must be resolved and some modifications must be made.

On the other hand, based from the responses of the contact tracers, it can be inferred that having a face-to-face seminar rather than an online meeting would yield better feedback. Through a face-to-face seminar, the app's purpose, features, and embedded security measures can be communicated better. Additionally, conducting a guided testing wherein testers can directly ask the developers for help and guidance would improve their understanding of the app.

Lastly, since having a stable internet connection is a limitation of this study, further studies may explore Progressive Web Applications to support offline functionalities especially on the general users interface.

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7 APPENDIX

7.1 UPTrace Testing Instructions for Users

Users will test UPTrace twice: once in the browser application and once in the Android application. They have to use a certain platform first (browser or Android) depending on what has been assigned to them by the researchers. This test simulates the user signing up/logging in and scanning QR codes of 2 entrances and 1 room in the following order:

1. User enters the entrance of Building A/C.
2. User enters Room 1 of Building A/C.
3. User enters the entrance of Building B/D.

Users have to make sure that they have a stable internet connection and a stable mobile signal. They must also have a timer which will be used in taking the time taken in scanning QR codes. Users may use the timer on their phone or on any other device.

Please read ALL the instructions first before you attempt the test.

1. Open the app/visit the website.
2. If this is your 1st time to test: Signup by filling out the necessary fields and by waiting and providing the OTP that will be sent to the registered mobile number. Feel free to click the (?) buttons for more information. If you are signing up using the browser app, please DO NOT USE THE "SIGN UP USING GMAIL" OPTION.
   If this is your 2nd time to test: Login by filling out the necessary fields.
3. After signing up/logging in, you are now directed to the homepage where information about UPTrace is displayed. Feel free to read this information. Do not touch any buttons yet.
4. We will be now using the Scan QR Code feature of the application. Prepare the QR codes attached for the 1st/2nd test depending on which test you're currently doing.
5. Scan the first QR code.
   If this is your 1st time to test: The first QR code is the Entrance of Building A.
   If this is your 2nd time to test: The first QR code is the Entrance of Building C.
6. Scan the second QR code.
   If this is your 1st time to test: The second QR code is Room 1 of Building A.
   If this is your 2nd time to test: The second QR code is Room 1 of Building C.
7. Suppose that you will be transferring to another building after some time. Please close the browser or mobile application and screen lock your phone (i.e. turn off the screen).
8. Unlock your phone.
9. Start the timer. Visit the website/open the mobile application.
10. Now, scan the third QR code.
    If this is your 1st time to test: The third QR code is the Entrance of Building B.
    If this is your 2nd time to test: The third QR code is the Entrance of Building D.
    After successfully scanning, stop the timer. Take note of the time taken since this will be needed in the survey.
11. If this is your 1st time to test:
    Click the "I Tested Positive" and "I Suspect to be Positive" buttons but DO NOT FILL OUT AND SUBMIT the form. This is only to check if the buttons are working.
    If this is your 2nd time to test: Suppose that after some time, you suspect to be positive (either through symptoms or positive direct contact) or tested positive. In the home page, click either the "I Tested Positive" or "I Suspect to be Positive" depending on your choice. Fill out the necessary information in disclosing your case.
12. Log out your account.
13. If this is your 1st time to test: Go back to 1 and perform the 2nd test.
    If this is your 2nd time to test: Testing ends here. You may now answer the survey form.

7.2 UPTrace Testing Instructions for UPHS

UPHS contact tracers will test the browser application. This test simulates the contact tracer signing up/logging in and using the following features:

1. Searching and filtering patients
2. Assigning patients to themselves
3. Accessing and downloading information of patients assigned to them, including their whereabouts and close contacts

Please read ALL the instructions first before you attempt the test.

1. Visit the website.
2. Signup by using Google Authentication, filling out the necessary fields and by waiting and providing the OTP that will be sent to the registered mobile number. Feel free to click the (?) buttons for more information.
3. After signing up, you are now directed to the homepage where information about UPTrace is displayed. Feel free to read this information. Do not touch any buttons yet.
4. Click the "Patients" button on the top right of the screen. This will display a list of patients who disclose their covid status (either suspected or tested positive).

5. Filter the patients by date by clicking the date and setting the date to "April 27, 2022". This should display a list of patients who disclosed their covid status on April 27, 2022.
6. Among the patients displayed, choose the patient whose contact number ends with the same number as your tester number in the email address that will be provided to you. For example, if you are Tester 1, then kindly choose the patient with contact number 09990000001.. You may view more information about the patient by clicking the "View More" button. Please take note of the contact number of your chosen patient as this will be used later for updating their status.
7. Suppose that you have already contacted your chosen patient. You may now assign them to yourself by clicking the "I contacted this patient" button.
8. View the whereabouts and possible close contacts of your chosen patient by clicking the "View Close Contacts" and "View Whereabouts" buttons as seen in the image below.
9. You may download these data by clicking the "Export" buttons.
10. Suppose that you have to update your chosen patient's status, you may search for a particular patient by clicking the "Patients" button on the top right of the screen and clicking the "Search" tab. You may now type your chosen patient's contact number in the search bar and click "Search" or press enter.
11. Suppose that your chosen patient has already tested negative. You are required to update the patient's status accordingly. Click the status of the patient and click the new status (confirmed negative).
12. Logout by clicking the "Logout" button on the top right of the screen.

7.3 UPTrace Survey Questions for Users

7.3.1 Understanding How well did you understand both applications?

1. I did not understand the purpose of the application, how to navigate it, and what will happen next after disclosing.
2. I only understood the purpose of the application.
3. I only understood how to navigate the application.
4. I only understood both the purpose of the application and how to navigate it.
5. I understood the purpose of the application, how to navigate it, and what will happen next after disclosing.

7.3.2 User Interaction How easy or difficult is it to use the app? (Separately asked for the mobile application and browser application.)

1. I find it difficult to sign up/log in, scan QR codes, and disclose.
2. I find it easy to sign up/log in, but difficult to scan QR codes, and disclose.
3. I find it difficult to sign up/log in, but easy to scan QR codes and disclose.
4. I find it easy to sign up/log in, scan QR codes, and disclose.
5. I find it easy to sign up/log in, scan QR codes, disclose, and navigate through different features.

7.3.3 Time Consumed in Scanning How much time did it take to successfully scan a single QR code provided by the researchers? (Separately asked for the mobile application and browser application.)

1. It took not more than 15 seconds to successfully scan a single QR code.
2. It took not more than 20 seconds to successfully scan a single QR code.
3. It took not more than 25 seconds to successfully scan a single QR code.
4. It took not more than 30 seconds to successfully scan a single QR code.
5. It took me more than 30 seconds to successfully scan a single QR code.

7.3.4 Privacy How secure do you feel in sharing your data with UPHS contact tracers?

1. I am not aware about what data is collected in the application.
2. I do not agree with the data that is needed in the application and I don't feel secure to share it.
3. I do not agree with the data that is needed in the application but I feel secure to share it.
4. I agree with the data that is needed in the application but I don't feel secure to share it.
5. I agree with the data that is needed in the application and I feel secure to share it.

7.3.5 Impact Assuming that this will be recommended to be used in UPD and you will be visiting UPD, how likely are you to use and recommend the application?

1. I am likely not to use this application consistently and not recommend it to others.
2. I am likely to use this application but not consistently.
3. I am likely to use this application consistently but not recommend it to others.
4. I am likely to use this application consistently and recommend it to others.

7.3.6 Additional Questions

1. Which application do you prefer: the Android app or the browser app? Why?
2. What difficulties, if any, did you encounter during the testing?
3. What other useful features or improvements do you think should be implemented?
4. What issues do you think are embedded in the application? (In case of a negative feedback, you may tell the reason for your choices here.)

7.4 UPTrace Survey Questions for UPHS

7.4.1 Understanding How well did you understand the application?

1. I did not understand the purpose of the application, how to navigate it, and what will happen next after assigning myself to a patient.
2. I only understood the purpose of the application.
3. I only understood how to navigate the application.
4. I only understood both the purpose of the application and how to navigate it.
5. I understood the purpose of the application, how to navigate it, and what will happen next after assigning myself to a patient.

7.4.2 Functionality Are the specified features working properly?

1. Searching and filtering patients, assigning a patient to a contact tracer and updating their status, and viewing and downloading patient information (including their whereabouts and close contacts) features are not working properly.
2. Only searching and filtering patients feature is working properly.
3. Only searching and filtering patients, and assigning a patient to a contact tracer and updating their status features are working properly.
4. Only assigning a patient to a contact tracer and updating their status, and viewing and downloading patient information (including their whereabouts and close contacts) features are working properly.
5. Searching and filtering patients, assigning patients to a contact tracer and updating their status, and viewing and downloading patient information (including their whereabouts and close contacts) features are working properly.

7.4.3 User Interaction How easy or difficult is it to use the app?

1. I find it difficult to search and filter patients, to assign myself to a patient and update their status, and to view and download patient information.
2. I find it easy to search and filter patients, but difficult to assign myself to a patient and update their status, and to view and download patient information.
3. I find it easy to search and filter patients and to assign myself to a patient and update their status, but difficult to view and download patient information.
4. I find it easy to assign myself to a patient and update their status, and to view and download patient information, but difficult to search and filter patients.
5. I find it easy to search and filter patients, to assign myself to a patient and update their status, and to view and download patient information.

7.4.4 Impact How likely are you to recommend UPHS to use this application in contact tracing?

1. I am likely not to recommend the application to be used by UPHS.
2. I am not sure if I will recommend the application to be used by UPHS.
3. I am likely to recommend the application to be used by UPHS after some modifications or improvements.
4. I am likely to recommend the application to be used by UPHS as it is.

7.4.5 Additional Questions

1. What difficulties, if any, did you encounter during the testing?
2. What other useful features or improvements do you think should be implemented?
3. What issues do you think are embedded in the application? (In case of a negative feedback, you may tell the reason for your choices here.)