Covid-19 Contact Tracing Application Adoption: A Technology Readiness Model Perspective

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Abstract. In late December 2019, there was an unforeseen outbreak of Coronavirus (COVID-19), which resulted in a global pandemic that claimed millions of lives. To allow individuals to travel freely and the economy to recover, government officials needed to be able to swiftly detect potential COVID-19 situations and track prospective encounters. There are numerous methods for doing contact tracing, one of them is to use contact tracking application. The COVID-19 contact tracing application allows for the tracking of people who encounter individuals who have COVID-19, regardless of where they are. The purpose of the research was to investigate the adoption of contact tracking applications through the theory of technology readiness in Nigeria. A cross-sectional survey was carried out using a non-probability sampling technique. Online questionnaires were sent via social media and email, with a total of 145 individuals taking part in the study. The data collected were analyzed using partial least squares (PLS) utilizing the SmartPLS-3 software to test the hypothesis generated by the research model presented in the study. The results obtained from the data collection and analysis revealed that six of the presented hypotheses were supported. Innovativeness was found to be strongly related to perceived usefulness while discomfort has a negative effect on perceived ease of use and usefulness. Implications of those findings are further discussed.

Keywords: Contact Tracing Application · COVID-19 · Technology Adoption · Readiness

1 Introduction

In late 2019, the first case of Coronavirus (COVID-19) identified and reported was in Wuhan, China. The continuous spread of virus resulted in severe acute respiratory syndrome-Coronavirus 2 (SARS-CoV-2), has led to a global pandemic. There are currently 186,164,398 confirmed cases, 170,302,144 recoveries and a total of 4,022,211 deaths worldwide as of July 8th, 2021 [1]. Some of the preventive measures implemented by countries in response to combating the spread of the virus includes the strict use of face mask, social distancing, self-isolation measures and imposing strict lockdowns [2]. However, the strict lockdowns significantly affect the economic sector as it leads to businesses shutting down and workers losing their jobs, leaving them unable

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to fend for themselves and family. Research has shown that a crucial way in which the spread of the virus can be reduced is identify people who may have encountered a confirmed case of the COVID-19, this can be done by contact tracing [3].

Contact tracing is a "process of identifying and providing supported quarantine to individuals who have been in contact with people who are infected with SARS-CoV-2 and can be used to find a source of infection by identifying settings or events where infection may have occurred, allowing for targeted public health and social measures" [4]. The manual method of contact tracing involves health workers conducting interviews with infected patients to identify people they may have encounter. The process may be effective, but it comes with its limitation ranging from [a] large number of well-trained health workers to conduct manual interview, [b] inability to identify every single person who have encounter the infected person [5]. Due to the several limitations in the manual process of contact tracing, several countries have found ways of adopting technological solutions to the process of combating the spread of COVID-19 by using contact tracing applications. These applications are dependent on the use of smartphones as it involves the use of proximity tracking tools to trace people who have come in close range with an infected person [6]. Other technologies such as characteristics tracking tools which are based on self-reported signs and symptoms are being adopted to help combat the spread of COVID-19 [7].

Several advantages to adopting COVID-19 contact tracing application include enhancing the traditional method of contact tracing, efficiency, a wide reach and helping to combat the spread of the virus. However, the effectiveness of these application is based on how willing people are to adopting them. Individuals have a lot of concerns when it comes to adopting contact tracing application, this ranges from safety, effectiveness, and privacy issues [8]. Hence, the aim of this research is to investigate the factors that would predict and inhibit the adoption of COVID-19 contact tracing application using the Technology Readiness Model as base framework. We asked the following questions: RQ1: What factors predict the adoption of contact tracing application? RQ2: What factors inhibit the adoption of contract tracing application?

2 Literature Review

Contact tracing is a procedure that involves identifying people who may have encountered an infected person while the person was an active carrier of a disease. This is a time-tested procedure initiated to monitor and control historical outbreaks like Tuberculosis, Lassa fever, Ebola, measles, and HIV [9]. According to the WHO (World Health Organization), contact tracing involves these three steps:

1. Contact Identification: "This requires the infected person recalling activities and roles of persons in-volved". 2. Listing Contacts: "This requires calling the names of potentially infected contacts". 3. Contact Follow-Up: "This requires monitoring any symptoms connected to the viral infection". The usual method of contact tracing involves manually carrying out interviews to trace people who must have met and infected individual. During the pandemic technological solutions are being put in place to enhance the manual method of contact tracing by enhancing contact tracing applications [9]. These applications solely depend on been installed on smartphones and rely on either global

positioning systems (GPS), Wireless Transmitter (Wi-Fi) or Bluetooth connection. The contact tracing application function on a framework which involves smartphones logging close contact with other smartphones running the same application [6].

2.1 Architecture

There are two types of contact tracing application centralized and decentralized.

- Centralized Architecture: Smartphones share anonymous user IDs with a central server, which uses the database to do contact tracking, risk analysis, and alert messaging to users. Detections are executed on centralized server with all information of individuals been transferred to the server.
- Decentralized Architecture: In place of a centralized server, smartphones perform contact tracing and alerting by downloading the contact database directly from the server. The smartphone performances as the local server and only transfers the information of infected people to a centralized server, contact matching is done locally with information been fetched occasionally from the server [10] (Fig. 1).

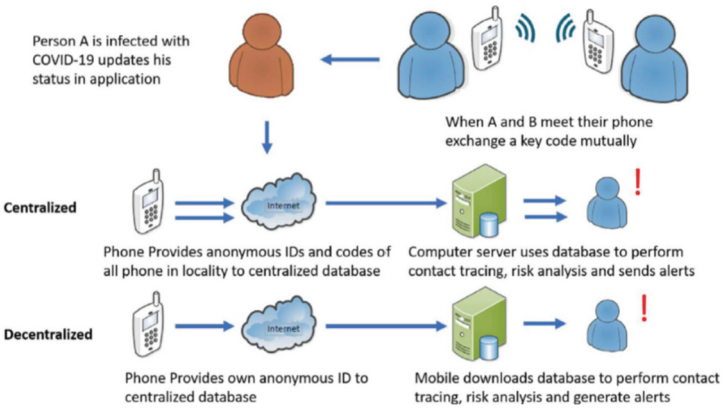

Fig. 1. Contact Tracing Architecture [10]

2.2 Adoption Theories

Adoption theories are used to highlight significant elements that encourage people to participate in specific behaviors [11]. It is used to investigate people and the decisions they make while accepting or declining a development [12]. There is no exact concept for understanding the behavioral shift that occurs when a person adopts a technology. Nevertheless, numerous adoption models from various areas have emerged throughout the years. For this research which is technology based the adoption theories explored include Diffusion of Innovation [13], Theory of Reasoned Actions [14], Technology Acceptance Model [15], Extensions of the Technology Acceptance Model [16], Technology Readiness [17] and Technology Readiness and Acceptance Model [18]. We further review the base model used in this study in the next section.

2.3 Technology Readiness

Parasuraman [17] refers to Technology Readiness (TR) as "*people's propensity to embrace and use new technologies*". Relaying on people's sentiments, principles, and perceptions towards technological products and services, it can be considered as state of mind determined by predictors and inhibitors when an individual tries to adopt new innovations [17, 19]; Based on this the Technology Readiness Index (TRI) was established to measure the use of technology instead of the capability of use. Technology Readiness is measured using four dimensions, optimism, innovativeness, discomfort, and insecurity. It is known that optimism and innovativeness are the positive predictors and discomfort, and insecurity are the negative inhibitors [20].

- Optimism: "A positive view of technology and a belief that it offers people increased control, flexibility, and efficiency in their lives."
- Innovativeness: "A tendency to be a technology pioneer and thought leader."
- Discomfort: "A perceived lack of control over technology and a feeling of being overwhelmed by it."
- Insecurity: "Distrust of technology and skepticism about its ability to work properly."

2.4 Technology Readiness and Acceptance Model

Lin et al. [18] introduces the Technology Readiness and Acceptance Model (TRAM) by integrating Technology Readiness (TR) and Technology Acceptance Model (TAM) components into a single framework. According to Lin et al. [18] technology readiness (TR) is an originator of both perceived usefulness and perceived ease of use, both of which impact customers proclivity to use e-services. He states that the integrated approach transfers the emphasis from service systems to customers suggesting that it is obvious that the models are connected since TAM assesses a system (system-specific) and TR measures broad technological views (individual-specific). When combining Technology Readiness Index (TRI) and Technology Acceptance Model (TAM), there are several ways in which it can be done. It could be done by examining the aggregate TRI dimension on the TAM construct of perceived usefulness and perceived ease of use [21]. It was discovered by Lin and Chang [22] that the aggregated TRI dimensions had a direct influence on the TAM usage intention construct. The alternative method is to examine the impact of the four TRI dimensions separately, hypothesizing that the dimensions of optimism and innovativeness have a positive influence on TAM constructs, while the remaining dimensions of discomfort and insecurity have a negative effect on TAM constructs [23, 24] (Fig. 2).

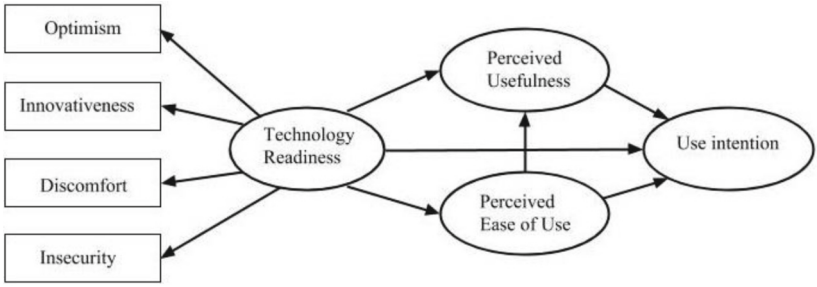

Fig. 2. Technology Readiness and Acceptance Model [18]

2.5 Research Model and Hypothesis Development

The research model (see Fig. 3) for this study was developed based on the previous adoption theories explained above. The research model integrates TAM [25] and TRI [26] to investigate the predictors and inhibitors of adopting COVID-19 contact tracing application. Figure 3 illustrates the research model used for this research.

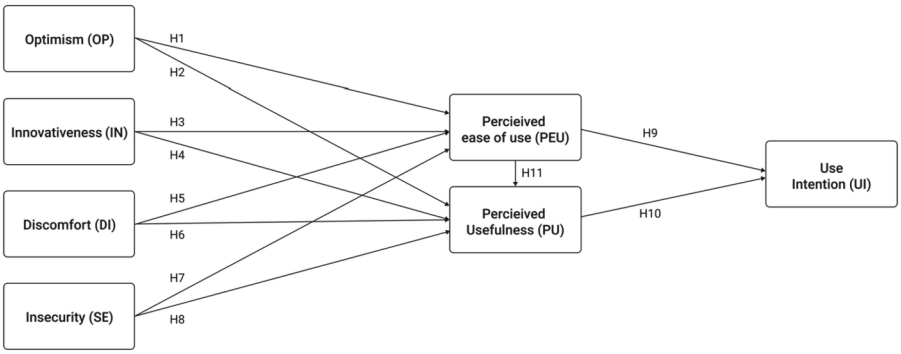

Fig. 3. Research Model

2.6 Hypothesis Development

Parasuraman [17] classifies optimism and innovativeness to be facilitators of technology in Technology Readiness theory. He defines optimism as "*a positive view of technology and a belief that it offers people increased control, flexibility, and efficiency in their lives.*" Individuals who are optimistic about adopting new technology are less likely to pay attention to the negative aspect of innovation. They perceive adopting new technology to improve their lives through efficiency, flexibility, and improvement in controls. Thus, people who are optimistic about innovation are likely to adopt COVID-19 contact tracing application as useful and easy to use. As a result, the following hypothesis was proposed:

H1. Optimism positively affects perceived usefulness in adopting contact tracing application.

H2. Optimism positively affects perceived ease of use in adopting contact tracing application.

The word innovativeness is widely used to quantify the "newness" of an innovation, according to [27]. Individuals who are categorized as "innovative" are more inclined than others to adopt fresh ideas [13]. Parasuraman [17] defines Innovativeness as "*a tendency to be a technology pioneer and thought leader*". Thus, people who have innovativeness are likely to adopt COVID-19 contact tracing application as useful and easy to use. As a result, the following hypothesis was proposed:

H3. Innovativeness positively affects perceived usefulness in adopting contact tracing application.
H4. Innovativeness positively affects perceived ease of use in adopting contact tracing application.

Discomfort is defined as "a feeling of being overwhelmed by technology and a perceived lack of control over it" [17]. Mukherjee and Hoyer [30] feel that complicated features on technology products have a negative impact on product assessment. Thus, individuals who feel a form of discomfort are less likely to adopt COVID-19 contact tracing application as useful and easy to use. As a result, the following hypothesis was proposed:

H5. Discomfort negatively affects perceived usefulness in adopting contact tracing application.
H6. Discomfort negatively affects perceived ease of use in adopting contact tracing application

According to the Parasuraman [17] Insecurity "implies a distrust of technology and doubt about its ability to perform properly". When it comes to adopting new technology, a high level of uncertainty creates a sense of danger, which is proven to have a detrimental influence on perceived ease of use and perceived usefulness. Thus, individuals who feel insecure is less likely to embrace COVID-19 contact tracing application as a helpful and simple. As a result, the following hypothesis was proposed:

H7. Insecurity negatively affects perceived usefulness in adopting contact tracing application.
H8. Insecurity negatively affects perceived ease of use in adopting contact tracing application.

According to the basic TAM model, researchers have been exploring the effect of Perceived usefulness (PU) and Perceived ease of use (PEU) on Use Intention (UI). Reports show that PU and PEU positively impact use intention [25]. However, there have been few research on the intention to adopt COVID-19 contact tracing application. As a result, the following hypothesis was proposed:

H9: Perceived ease of use has a positive influence on intention to adopt contact tracing application.
H10: Perceived usefulness has a positive influence on intention to adopt contact tracing application.

The relationship between perceived ease of use and perceived usefulness has been studied by researchers. Both are thought to be linked. In the context of adopting COVID-19 contact tracing application, a user who deems COVID-19 contact tracing application easy to use would develop a disposition to see them as useful. As a result, the following hypothesis was proposed:

H11: Perceived ease of use has a positive influence on perceived usefulness in adopting contact tracing application.

3 Methodology

To evaluate the derived hypothesis, a cross-sectional survey approach was used in this study. The questionnaire was distributed through the mail and social media in order to optimize response rate and achieve scalability. The questionnaire was created using Google Forms because it not only provides functions to limit what the respondent can answer while also ensuring that the participant is enter the correct data, but it also provides a clear and appealing visual layout, which is important for reliability, validity, and response rate [28]. For this research the non-probability sample was utilized. Non-probability sampling comprises non-random selection based on convenience or other criteria, allowing for more convenient data collection. Using a probability sample is not feasible as a list of all members of the population will be needed in order to draw randomly the desired sample. Using the convenience sampling, the participants for this research were chosen from the general populace since the Nigerian population is too huge to analyze, therefore convenience sampling is a quick, cost-effective, and convenient way to get a sample. The survey utilized for this study was conducted in November 2021. It was circulated via email and social media for people in Nigeria to fill out the online questionnaire. For research using quantitative analysis it is important to select the appropriate data analysis method. The data for this research was evaluated using PLS-SEM (Partial Least Squares - Structural Equation Modelling) and SmartPLS 3.0. SmartPLS 3.0 is a computer program that calculates and evaluates research data and conceptual models [29].

4 Analysis

The questionnaire used for this research was distributed to 200 participants, and a total of 145 were returned, producing a 72.5% response rate. A total of 145 participants data were analyzed after data screening and cleaning. According to the data, males made up 57.9% of the participants, while females made up 42.1%. The majority of the participants were between the ages of 23 and 27 and 28 and 32, according to the statistics. According to the data analysis, 41.4% of the participants were okay with sharing their location on their device, while 58.6% seem to not be okay with the idea sharing their location on their device. Furthermore, 75.8% of participants said they had never used a contact tracing application, while 24.2% said they had used a form of contact tracing application (Table 1).

Internal reliability was measured using composite reliability and are above the recommended 0.70 value [31]. Convergent and discriminant validity were examined using

Table 1. Descriptive Analysis

Description	Options	Frequency	Percentage
Gender	Male	84	57.9
	Female	61	42.1
Age	18–22	22	15.1
	23–27	45	31.0
	28–32	30	20.7
	33–37	24	16.6
	38–42	14	9.7
	43 and above	10	6.9
Education	Diploma or below	38	26.2
	Bachelors	67	46.2
	Masters	25	17.2
	Doctorate	15	10.4
Location Sharing	Yes	60	41.4
	No	85	58.6
Used Contract Tracing Before	Yes	35	24.2
	No	110	75.8

SmartPLS Version 3.0 [32]. Factor loadings are above 0.6 as recommended by [33]. The average extracted variance (AVE) are above 0.5 [34]. Discriminant validity has been established by the square root of the AVE which is greater than the correlations among all the construct (from 0.73 to 0.93). Based on the above criteria, perceived product risk was culled from further analysis.

5 Discussions

Based on the literature review, the research proposed eleven hypotheses. The results shows that six of the proposed hypotheses were supported and proved useful in predicting intentions of adopting COVID-19 contact tracing application while four of the hypotheses were not supported. According to the analysis, H4, H5, H6, H8, H9, and H10 were supported, however H1, H2, H3, H7 and H11 were not supported. Table 2 provides an overview of the hypothesis testing results. Contrary to previous studies [40, 41, 43, 46], the results indicate that both optimism and innovativeness are not significantly related to perceived ease of use.

As technology readiness in influenced by people's personalities and demographics [21] and given the context of Covid-19, this may have adversely affected the positive attitude that our respondents had with regards to the benefits of contact tracing application. As high optimists are very familiar with technology and are unlikely to focus on adverse events [41], the Covid-19 pandemic may have stifled the optimism of our

Table 2. Hypotheses Test

	Hypothesis	Path (β)	T-Value	P-Value	Supported
H1	OP -> PEU	0.03	0.38	n.s	No
H2	OP -> PU	−0.11	1.92	n.s	No
H3	IN -> PEU	−0.09	1.084	n.s	No
H4	IN -> PU	0.28	3.180	P < 0.001***	Yes
H5	DI -> PEU	−0.72	10.29	P < 0.001***	Yes
H6	DI -> PU	−0.28	2.662	P < 0.01**	Yes
H7	SE -> PEU	−0.01	1.58	n.s	No
H8	SE -> PU	−0.36	5.73	P < 0.001***	Yes
H9	PEU -> UI	0.35	3.24	P < 0.001***	Yes
H10	PU -> UI	0.21	2.24	P < 0.05*	Yes
H11	PEU -> PU	0.17	1.55	n.s	No

Note: n.s = non-significant; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ (Using a single line test and bootstrapping with 1,0000 subsample). OP: Optimism, IN: Innovativeness, SE: Insecurity, DI: Discomfort, PU: Perceived Usefulness, PEU: Perceived Ease of Use, UI: Usage Intention

respondents. Moreover, the lack of optimism suggests that the respondents believe that they will not have better control, flexibility and confidence when using contact tracing application [21].

In line with Nugroho and Fajr [43], the result shows that innovativeness is strongly related to perceived usefulness while being non-significant with perceived ease of use. The results demonstrate that innovative individuals are more likely to perceive contact tracing application as being useful rather than being easy to use. Walczuch et al. [24] contend that innovative individuals are familiar with technology and expect technology to meet their demands, hence, the positive relationship with PU. Innovativeness generally measures the degree that individuals perceive themselves as being at the forefront of technology adoption [23]. Innovative people are generally more open to new ideas [35]. It has been demonstrated that an individual's level of creative mindset is a critical factor in his or her acceptance of new technology [36].

Consistent with previous studies [41, 42], the findings also indicate that discomfort has a strong negative significant relationship with both perceived usefulness and perceived ease of use. Insecurity has a strong negative significant relationship with perceived usefulness. Discomfort deals with the fear and concerns that individuals have with regards to the contact tracing application. Therefore, individuals with high level of discomfort towards technology are more likely to perceive adopting COVID-19 contact tracing application as difficult to use and not useful [41].

Individuals lack of trust may contribute towards them feeling insecure towards adopting contact tracing application. Contact tracing app will not only require users to display their location as well as places where they have been recently. Lack of trust has been an important inhibitor to technology adoption [44, 47, 49]. Research defined trust as the

willingness to be vulnerable to others and expecting positive intentions towards ones Interest [48].

Other reasons include privacy concerns. Studies involving privacy have shown that privacy risks have a negative effect on use intentions [40, 51]. Harboth and Pape [51] argue that privacy is one of the main reason for the lack of adoption of contact tracing application as individuals were apprehensive about government surveillance [52], leakage of data to third parties [53], exposure of social interactions and secondary data use [54]. These findings have significant implications for Governments trying to use technology to better track and safeguard the population. Governments should work towards alleviating concerns related to insecurity and discomfort with the technology through appropriate training, concerted awareness campaigns. To further alleviate such concerns, the legal implications of such a technology should be looked into. Finally, obtaining a critical mass of users in the first instance could further increase the adoption of the service [55]. Based on TAM model, H9 and H11 were supported. Based on the TAM and numerous studies, the two main predictors of acceptance, perceived useful and ease of use have significant relationship with usage intention. Hypothesis H11 was not supported. It is widely acknowledged that perceived ease of use (PEU) contributes to perceived usefulness (PU) [37, 38]. This is based on the theoretical argument that some user-friendly technologies could be perceived as useful, but not all useful technologies are user-friendly [23]. Overall, the model used predicts 53% in PU and 49% in PEU and 24% of BI.

6 Limitations

To begin, this study was done with a limited sample size from a big population in Nigeria, and the findings obtained cannot properly establish the general community's desire to fully use contact tracing application. Individual opinions change over time, and the findings of this study reflect individual feelings during the time of the crisis. Therefore, further study should be done in the future to obtain more accurate data. Finally, this research depended on quantitative data collecting and analysis. Several academic researchers have emphasized the need of integrating qualitative analysis while studying technology adoption to provide extra insights [39]. Merging qualitative and quantitative approaches in a mixed-method design can further lead to better understanding of adoption of contact tracing apps.

7 Conclusion

The spread of COVID-19 has resulted in a pandemic, with millions of people affected and thousands of deaths globally. Many governments' have put in place strict confinement measures has a way to delay spread of disease and allowed health-care institutions to care for the infected. Various techniques for tracking have been proposed. As a result, contact tracing application has been proposed in a bid to de-escalation the spread of the virus while increasing population safety. The use of contact tracing technology has shown to be useful in countries like South Korea, who have been able to adopt the use of the technology and have been able to maintain the spread of the virus while reactivating

its economy due to the use of contact tracing technologies. The research results suggest that the intention to use tracing applications is driven by its perceived usefulness and perceived ease of use. Innovativeness was found to positively influence perceived usefulness while discomfort and insecurity negatively affect usefulness. The findings also demonstrate that discomfort reduces ease of use. This data can be useful to developers that utilize geolocation, as well as governments who must decide whether to use it and what privacy issues it entails. These findings have significant implications for Governments trying to use technology to better track and safeguard the population. Governments should work towards alleviating concerns related to insecurity and discomfort with the technology through appropriate training, concerted awareness campaigns. To further alleviate such concerns, the legal implications of such a technology should be looked into. Finally, obtaining a critical mass of users in the first instance could further increase the adoption of the service. This research backs up the idea that users will be willing to adopt a contact tracing application if they trust it and appreciate its functionality and ease of use, and that privacy concerns are taken into consideration.

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