Critical Overview of the Use of Contact Tracing Apps in the Context of the COVID-19 Pandemic

Arturo González[1][a], Christian von Lücken[1][b], Julio Paciello[2][c], Tito Ocampos[2][d] and Juan Pane[2][e]
[1]*Unversidad Nacional de Asunción, Facultad Politécnica, San Lorenzo, Paraguay*
[2]*Centro de Desarrollo Sostenible, Asunción, Paraguay*

Keywords: Contact Tracing, Mobile Application, COVID-19.

Abstract: Contact tracing determines the chain of contacts of an infected person to isolate them. Implementing contact tracing requires an enormous effort that generally falls on the different governments and their respective health authorities. Emerging technologies can be quite useful in supporting contact tracing. The most relevant advantages of using mobile applications based on digital technologies to perform contact tracing are the fast collection of reliable data and the rapid detection of possible contacts at risk. However, despite these advantages, many countries have not reported a high penetration of these tools. As a relevant and actual research area, this paper presents a critical overview of the current literature regarding contact tracing applications to answer the following research questions: What is the most used technology to develop contact tracing apps? What were the main lessons on using contact tracing applications so far?, How are ethics, privacy, and security issues handled?, What is the use that is given to the data collected by the applications, and what happens to them? Who applies these types of tools, and what implications did they have?

1 INTRODUCTION

At the end of 2019, World Health Organization (WHO) offices in Wuhan, Hubei Province of China, received reports of pneumonia's first cases with an unknown cause. A new virus from the coronavirus family (CoV), called severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), was identified. Consequently, the disease was named by the WHO as Coronavirus Disease 2019 (COVID-19). From there, the world would go through one of the worst crises after World War II (Otoya-Tono et al., 2020).

As of this article's writing date, the total number of infected by COVID-19 amounts to more than 90.759.370 and with a record higher than 1.963.169 confirmed deaths. It is important to note that currently, the most contagious region is America, with more than 40.187.505 infected, widely surpassing Europe (29.510.450), Southeast Asia (12.370.101),

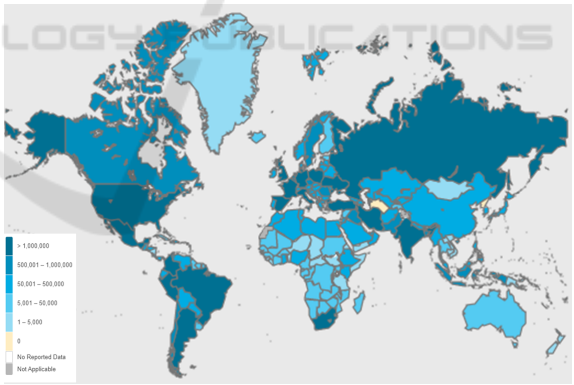

Figure 1: COVID-19 World Map (WHO, 2020).

and the Eastern Mediterranean (5.252.810), Africa (2.210.137), and the West Pacific (1.227.622), thus becoming the epicenter of current infections (See Fig. 1) (WHO, 2020).

Since the beginning of 2020, in the absence of effective treatment or vaccines for COVID-19, governments worldwide have been taken many non-pharmacological interventions (NPIs) to contain or mitigate the spread of the disease with health, social, and economic consequences. The test and trace strat-

[a] https://orcid.org/0000-0001-5672-3679
[b] https://orcid.org/0000-0002-2198-1237
[c] https://orcid.org/0000-0003-3196-5625
[d] https://orcid.org/0000-0002-4924-5995
[e] https://orcid.org/0000-0003-2607-4027

González, A., von Lücken, C., Paciello, J., Ocampos, T. and Pane, J.
Critical Overview of the Use of Contact Tracing Apps in the Context of the COVID-19 Pandemic.
DOI: 10.5220/0010480400910099
In *Proceedings of the 6th International Conference on Complexity, Future Information Systems and Risk (COMPLEXIS 2021)*, pages 91-99
ISBN: 978-989-758-505-0

egy, when applicable, becomes one of the best contention alternatives to deal with the spread without requiring more extreme measures (Jahnel et al., 2020). Contact tracing determines the chain of contacts of an infected person to isolate them. Implementing contact tracing requires an enormous effort that generally falls on the different governments and their respective health authorities (Mbunge, 2020).

Emerging technologies can be quite useful in supporting contact tracing (Ahmed et al., 2020). Digital contact tracing through smartphones' applications is a viable alternative to support this work (Jahnel et al., 2020). This possibility is practically a fact in several countries such as Singapore, Australia, Austria, Israel, Germany, Qatar, among others, which have already adopted the use, to a greater or lesser extent, of different contact tracing applications.

The most relevant advantages of using mobile applications based on digital technologies to perform contact tracing are the fast collection of reliable data and the rapid detection of possible contacts at risk. However, despite these advantages, there have not been many countries reporting a high penetration of these tools (MIT, 2020). The global debate revolves around the relevance and usefulness of contact tracing applications, so it is always timely to address this issue. In this sense, this work presents a critical description of contact tracing applications based on a systematic review of the literature related to the area. The objective of this work is to understand the experiences and assessing the implications of contact tracing app's in the framework of COVID-19.

This work organization is as follows. Section 2 provides a brief overview of the recent contact tracing applications and their uses in COVID-19; Section 3 is concerned with the research methodology applied into the study; Section 4 presents the survey results and discussions; and finally, Section 5 gives a summary and conclusions.

2 BASIC CONCEPTS AND BACKGROUND

2.1 Applications and Their Uses in COVID-19 Contact Tracing

Contact tracing consists of identifying and following the possible routes of transmission of a particular infection in a population to determine people who have been exposed and inform them in such a way they can isolate themselves (Yasaka et al., 2020). The strategy has the clear potential to reduce contagion. In general, contact tracing is carried out by the countries' health authorities, either by a manual interview or not, of confirmed or suspected cases to collect data on possible contacts that the infected person had with others (Ahmed et al., 2020).

Given the situation experienced by the COVID-19 pandemic, many researchers have sought to find technological solutions to automate the entire contact tracing process in such a way as to reliably and quickly obtain the contacts of people infected in such a way to minimize risks (Ahmed et al., 2020). In this context, contact tracing based on smartphones and applications presents a possible solution that would limit the transmission of both COVID-19 and other diseases; however, there are several concerns regarding this type of tools (Yasaka et al., 2020).

Digital tools can be extremely useful to support the measures recommended by the World Health Organization (WHO), which are a test, trace, isolate, and put in quarantine. At least it would be very useful to improve data flows digitally and also for proximity tracing via geolocation, which would significantly speed up the reporting and contact tracing processes (Vokinger et al., 2020).

According to (Vokinger et al., 2020), the typology of different applications and technologies in the context of COVID-19 that are aimed at the general public are:

- **Proximity Tracing Apps:** store upcoming contacts in a certain period of time. They can include notification systems and alerts in case of confirmation of COVID-19 diagnoses.
- **Patient Diaries:** a platform for monitoring the symptoms and risks of exposure to a specific population or group.
- **Crowd-sourced Surveillance:** a platform for monitoring symptoms at the population level.
- **Tele-health:** Platform for self-assessments and online consultations with medical professionals.
- **Mental Health Interventions:** digital platforms to support mental health.

As for the architecture generally adopted for the data collection aspects of the tracing applications, there are three. These systems are the most used to develop applications. These are the approaches (Ahmed et al., 2020) (See Table 1 for some examples):

- **Centralized:** There is a central server that performs basic functions such as storing personal information, generating contact records, risk analysis platform, and notification of identified close contacts.

- **Decentralized:** This architecture proposes the transfer of central functionalities to the user's devices, leaving the server with minimal participation in the entire contact tracing process.
- **Hybrid:** The hybrid architecture proposes that these functionalities be divided between the server and the devices.

Table 1: Some examples of applications with the three architectures mentioned (Ahmed et al., 2020).

Architecture	App	Description
Centralised	TraceTogether	TraceTogether was the first major Bluetooth contact tracing app.
Centralised	CovidSafe (AU)	Australian experts have criticized the government for a lack of transparency and non-responsiveness to privacy issues.
Decentralised	CovidSafe-PACT (WEST-COAST)	Is a tracing protocol proposed by researchers from the University of Washington.
Decentralised	SwissCoviD - DP-3T	Is a protocol proposed by a consortium of universities and organisations from Europe led by EPFL, Switzerland
Hybrid	ConTra CORONA	Is a hybrid protocol proposed by German researchers from the FZI Research Center for Information Technology and Karlsruhe Institute of Technology
Hybrid	EpiOne	Has been proposed by a team of researchers led by the University of California at Berkeley

At the time of writing this article, (MIT, 2020) presented a very up-to-date (and freely accessible) list of the most used applications in some countries. It can be clearly seen that, in countries like India, although there are a large number of users for the "Aarogya Setu" application, it only represents 12.05% of the population. On the other hand, the "TraceTogether" application in Singapore has achieved 80% penetration in its population (See Table 2).

Table 2: Contact tracing applications with the largest number of users. (MIT, 2020).

Country	App	Users	Penentration
India	Aarogya Setu	163.000.000	12,05%
Vietnam	BlueZone	20.000.000	20,93%
UK	NHS COVID-19 App	19.000.000	28,51%
Germany	Corona-Warn-App	18.000.000	21,68%
Turkey	Hayat Eve Sığar	14.186.000	17,30%
Italy	Immuni	9.769.449	16,19%
Japan	COCOA	7.700.000	6,09%
Australia	COVIDSafe	7.160.909	28,64%
Saudi Arabia	Tawakkalna	7.000.000	20,77%
Canada	COVID Alert	5.314.026	14,03%
Indonesia	PeduliLindungi	4.600.000	1,72%
Singapore	TraceTogether	4.511.200	80,00%
Qatar	Ehteraz	2.531.620	91,00%
Finland	Koronavilkku	2.500.000	45,31%

2.2 Related Works

A systematized study to identify the applications for smartphones used to fight COVID-19 was carried out by (Collado-Borrell et al., 2020), which can be seen in the early 2020s of the trend of this type of tool. At the time of the study, the vast majority of developed applications are run by governments, and approximately two-thirds of all applications were made in Europe and Asia.

On the other hand, (Davalbhakta et al., 2020) carried out a complete systematic review of the smartphone applications used in the framework of the COVID-19 pandemic, the main result of which is a very useful characterization of the most successful applications in different regions of the world to date. For a particular case study in India, (Bassi et al., 2020) conducted a general review of applications available for use in the framework of COVID-19.

In the study carried out by (Ahmed et al., 2020), the authors focused on a review of the applications for smartphones and addressed the subject in a very comprehensive way. The work approaches the most common architectures of contact tracing applications, issues related to privacy and security aspects, issues concerning users, and even the path of future research.

3 METHODOLOGY

This research presents a critical overview of COVID-19 contact tracing mobile applications. The primary objective is to report the use of contact tracing apps

in the framework of COVID-19 in countries and critically describe their implications. To achieve this goal, research questions were elaborated and a systematic literature review was carried out. The final result is a document where the results obtained are presented in a summarized way. The process is detailed in Fig. 2 and it was conducted following the methodological framework of (Arksey and O'Malley, 2005; Lobato et al., 2013).

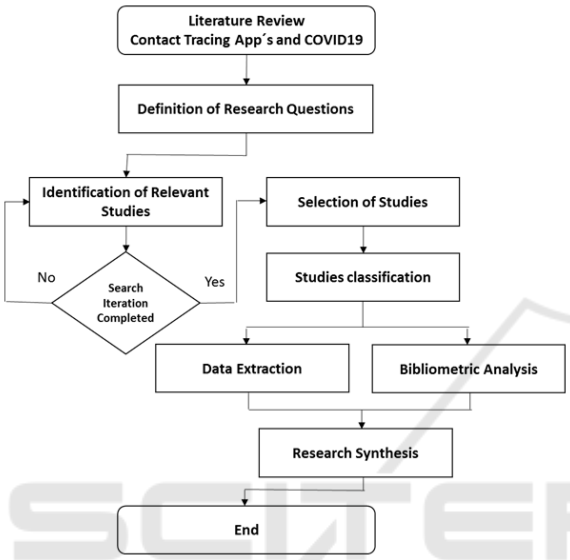

Figure 2: Steps of the Applied Methodology.

Step 1. Definition of the Research Questions. The starting point was the definition of the following research questions (See Table 3).

Table 3: Research Questions.

RQ#	Description
RQ1	What is the most used technology to develop contact tracing apps?
RQ2	What were the main lessons on using contact tracing applications so far?
RQ3	How are ethics, privacy and security issues handled?
RQ4	What is the use that is given to the data collected by the applications and what happens to them?
RQ5	Who applies these types of tools and what implications did they have?

Step 2. Search for Relevant Studies[1]**.** The purpose of this study is to be as complete as possible in the identification of primary studies to answer the research questions; for this, the Scopus database was chosen since it is one of the most used and comprehensive among all available. Within this database, two search iterations were performed considering the following selection commands (See Table 4). The search was conducted in late November 2020.

Table 4: Search Queries Made.

#	Query	Results
1	TITLE-ABS-KEY("contact" AND "tracing" AND "COVID-19")	546 documents
2	TITLE-ABS-KEY("contact" AND "tracing" AND "COVID-19" AND "apps")	46 documents

Step 3. Selection of Studies. The following inclusion and exclusion criteria were defined (See Table 5).

Table 5: Exclusion and Inclusion Criteria.

Selection criteria	Exclusion criteria
Articles that study and/or propose the use of applications for contact tracing	Posts found in the search that could not be accessed
Articles of position and commentary on the subject	Publications with a little approach to the subject
Review articles that address the topic	Posts from Unknown Sources
Studies that answer at least one research question.	

Step 4. Classification of the Studies. Applying the inclusion and exclusion criteria, an exhaustive reading of the identified articles was carried out. There were selected 39 articles which are presented in the work results.

Step 5. Bibliometric Analysis. To obtain an overview of the search results, a bibliometric analysis on the query outcomes using the Biliometrix tool (Aria and Cuccurullo, 2017) was used.

Step 6. Data Extraction. Table 6 presents the list of analyzed documents. Within these work, the necessary information to address the research questions was extracted.

Step 7. Research Synthesis. in this step, it was possible to summarize, integrate, combine, and compare the results of different studies on a topic based on the different specific research questions presented in this work (Arksey and O'Malley, 2005; Lobato et al., 2013).

[1]**Obs:** The two BibTex files resulting from the searches, are available in: **http://bit.ly/3inkPTJ**

Table 6: Documents analyzed in this work.

Type	Articles
Editorial, Comment and Position Articles	(Parker et al., 2020), (Morley et al., 2020), (Editorial, 2020), (Rowe et al., 2020), (Michael and Abbas, 2020), (Cioffi et al., 2020), (Rizzo, 2020), (Klar and Lanzerath, 2020), (Lucivero et al., 2020), (Hsu, 2020).
Review Articles	(Ahmed et al., 2020), (Davalbhakta et al., 2020), (Collado-Borrell et al., 2020), (Bassi et al., 2020).
Technical Articles	(Yasaka et al., 2020), (Vokinger et al., 2020), (Kitchin, 2020), (Trang et al., 2020), (Urbaczewski and Lee, 2020), (Nanni et al., 2020), (Liang, 2020), (Mbunge, 2020), (Bhatia et al., 2020), (Ramakrishnan et al., 2020), (Jahnel et al., 2020), (Galloway, 2020), (Yamamoto et al., 2020), (Ausín and Martínez, 2020), (Sharma et al., 2020), (Joo and Shin, 2020), (Borra, 2020), (Rowe, 2020), (Hoffman et al., 2020), (Goggin, 2020), (Klingwort and Schnell, 2020), (Vitak and Zimmer, 2020), (Scassa, 2021), (Altmann et al., 2020), (Kaspar, 2020).

4 RESULTS AND DISCUSSIONS

4.1 Bibliometric Analysis

As a result of searches made in the context of this work, Fig. 3 shows that most of the literature found corresponds to works carried out in the US, UK, Germany, and others. In general, the scientific production that addresses this topic is mainly concentrated in Europe and North America, including expanding the network of contacts between researchers. The country production and collaboration map is in Fig. 4.

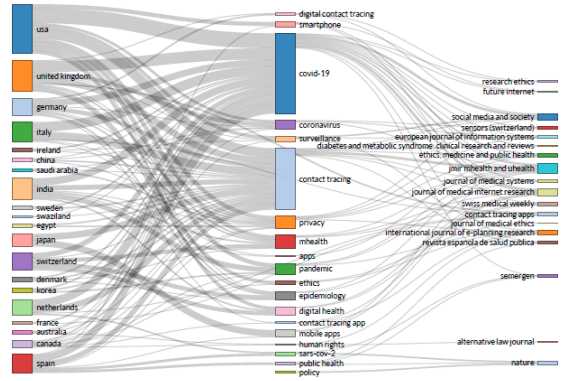

Figure 3: Country-Keywords-Sources Relations.

From Fig. 4, it is worth to note that most of the studies related to contact tracing applications concentrate in high-income countries, where the use of smartphones may be considered ubicuos. In comparison, large regions such as Latin America and Africa report few works.

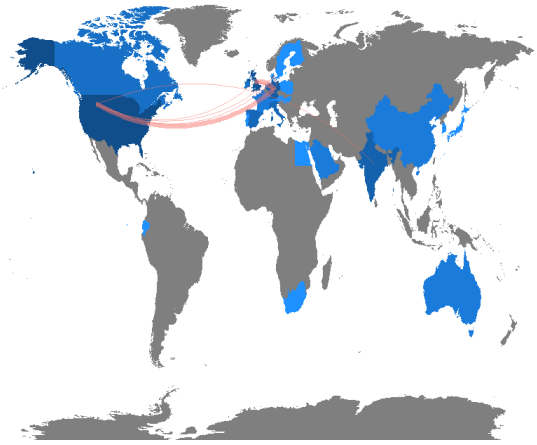

Figure 4: Country production and collaboration map of contact tracing applications studies.

At the time of writing this work, the ten most cited articles that address contact tracing apps' development issues are those in Fig. 5. Thus, these works can be seen as an introductory reading guide to entering the subject. Also, it is worth noting the high dynamism of scientific production in the area.

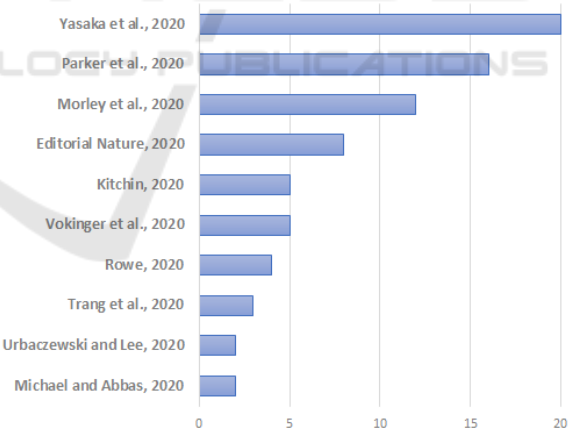

Figure 5: Most cited documents addressing contact tracing apps.

4.2 Survey Results

4.2.1 RQ1: What Is the Most Used Technology to Develop Contact Tracing Apps?

All Contact tracing Applications are mainly based on each person's location and the proximity of them to other people. That requires, in essence, the location

via GPS and Bluetooth for close contacts. In addition, to add precision, QR codes can be used to establish people's access points, among other tools (Kitchin, 2020; Borra, 2020; Ahmed et al., 2020; Hsu, 2020; Scassa, 2021; Mbunge, 2020).

The use of the technologies mentioned above and their possible benefits and implications in decision-making for policymakers was widely debated, and it remains only to improve the efficiency and effectiveness of new technologies as a response to COVID-19 (Ramakrishnan et al., 2020; Mbunge, 2020).

It is very difficult to provide an up-to-date figure and even more so in refereed publications given the high dynamism of technology use in contact tracing apps. But based on (Woodhams, 2020), at the end of October 2020, approximately 26% of applications were registered with a unique base in GPS technology, 51% with a unique base in Bluetooth, and 23% used both technologies. It is possible to freely access the (MIT, 2020) database to follow the applications used worldwide in a very up-to-date manner.

4.2.2 RQ2: What Were the Main Lessons on using Contact Tracing Applications So Far?

Contact Tracing Apps are an important tool in the fight against COVID-19. Numerous cases can be determined from countries where contact tracing applications have been recorded, mainly in the United States and countries in Europe and Asia (Ramakrishnan et al., 2020; Mbunge, 2020; Scassa, 2021; Hoffman et al., 2020). However, at present, very few countries have exceeded the barrier of 60% penetration (See Table 2) required for these applications to be really effective (MIT, 2020).

Several studies have been conducted to quantify people's motivation to use Contact tracing Apps. The Study conducted by (Kaspar, 2020) showed very low motivation to use the applications. On the other hand, (Joo and Shin, 2020) identified the issue of privacy as a predominant factor in the use of these types of tools.

Other models like (Rowe et al., 2020) shows a model of the causes of failure of the public address regarding the use of contact tracing applications. Instead, (Trang et al., 2020) shows the phenomena and topics for mass acceptance of applications.

There is still much debate about the effectiveness and usefulness of using contact tracing platforms. From the basic problem of privacy and security to matters such as the representativeness of users, even this would make the tools not useful in the field (Goggin, 2020; Klingwort and Schnell, 2020).

4.2.3 RQ3: How are Ethics, Privacy and Security Issues Handled?

Issues concerning privacy and subsequently ethics and security were addressed, to a greater or lesser extent, in practically all the articles selected and reviewed.

Since the first semester of 2020, ethics, privacy, and security were the focus of debates in what would be the beginning of the Contact tracing Applications. Contributions from (Editorial, 2020; Parker et al., 2020; Morley et al., 2020; Klar and Lanzerath, 2020; Lucivero et al., 2020) emerged as initial points in the debate, where the possible advantages, disadvantages, implications and challenges to be faced were discussed.

In the second half of 2020, the privacy debate became a hotly debated topic. In France, the implications of the use of applications had a strong impact on privacy, which subsequently impacted the low number of users (Rowe, 2020). In the United States, Australia, Singapore, and other countries with outstanding starts in terms of downloads, they did not continue that path in terms of the use of contact tracing applications and the feeling that these platforms present a high risk, generates mistrust, and affects to its use directly (Michael and Abbas, 2020; Cioffi et al., 2020; Hsu, 2020; Rizzo, 2020).

Certainly, the possibilities of the usefulness of contact tracing applications are enormous but ethical aspects, especially privacy and security, play too important a role for the successful implementation in many countries and it is something that must be taken into account (Scassa, 2021).

4.2.4 RQ4: What Is the Use that Is Given to the Data Collected by the Applications and What Happens to Them?

The main idea of contact tracing applications lies in the rapid monitoring of the virus transmission chains for the early detection of outbreaks in a fast, safe and efficient way (Nanni et al., 2020). This requires data that must necessarily respect users' privacy, that they are of quality, and that they are representative (large-scale). The big issue here is the handling of the data and what would be the utility of these.

In China, for example, the use of health codes (multi-color QR codes) in public spaces is a successful case of using user-generated data for rapid outbreak detection (Liang, 2020). On the other hand, (Vitak and Zimmer, 2020) asserted that the data generated by the applications must go through a comprehensive analysis since the convenience of sharing lo-

cation and health data depends on who will have access to the aforementioned data.

Another very interesting view on the data generated as a source of data from different models to characterize the contagion dynamics in different regions with people of different backgrounds, with the use of different methodologies, is a considerable possibility that should not be neglected and it is approached in several studies, and conceptual proposals (Yasaka et al., 2020; Yamamoto et al., 2020; Sharma et al., 2020; Urbaczewski and Lee, 2020).

4.2.5 RQ5: Who Applies These Types of Tools and What Implications Did They Have?

Most of the promoters and implementers of contact tracing applications are the governments of each country (Mbunge, 2020). In general, the application is tied to local public policies and how each place addresses the pandemic, as well as national privacy and security regulations (Bhatia et al., 2020; Vokinger et al., 2020).

After having exhausted the quarantine policies, many of the policymakers in the different countries have returned to the traditional contact tracing (Scassa, 2021). In particular, the case of Latin America, which at the time of writing this article has become one of the most contagious regions, does not present an implementation of any contact tracing application, or at least in a representative way (MIT, 2020).

5 CONCLUSIONS

The COVID-19 pandemic is part of the present and the near future; therefore, it will continue to affect the activities of all people worldwide. All contact tracing tasks currently carried out in all countries are of vital importance to slow the advance of this disease.

A critical and fairly comprehensive report on the use of contact tracing applications has been made, answering clearly and summarizing the research questions proposed for this study. The general report of the current situation gives a general overview of the technologies used for developing the different applications (GPS, Bluetooth, and GPS / Bluetooth) obviously with different complements architectures and protocols.

In general, ethical issues, especially privacy and security, play a fundamental role in the literature's current debate. The value of the data and its usage can generate distrust and caution in some users and cause these digital tools not to achieve the required penetration for a practical and useful operation.

Despite all the available technology and the many digital tools for contact tracing, it has not been successfully implemented at a level representative enough in at least the vast majority of countries, in such a way that it can represent a real aid of fighting against COVID-19.

As a recommendation for future work, and based on the presented work, it could be important to consider a focus on developing contact tracing tools or applications for those who have a greater risk of contagion and, therefore, more significant potential for transmitting the infection, as are medical doctors, nurses, and so on. Also, it may be useful to use contact tracing to determine the relations existing in corporate offices and industries to determine those who are more exposed or change the flow of activities to reduce the contacts that some users may have. In addition, it is important to know the current situation of the use of contact tracing applications in developing countries, especially in Latin America, in such a way as to consider the possibility of complementing prevention, contact tracing and case containment efforts of COVID-19 in the countries of the region.

ACKNOWLEDGEMENTS

This work is supported by CONACyT-Paraguay under the PINV20-184 project grant.

REFERENCES

Ahmed, N., Michelin, R. A., Xue, W., Ruj, S., Malaney, R., Kanhere, S. S., Seneviratne, A., Hu, W., Janicke, H., and Jha, S. K. (2020). A survey of covid-19 contact tracing apps. *IEEE Access*, 8.

Altmann, S., Milsom, L., Zillessen, H., Blasone, R., Gerdon, F., Bach, R., Kreuter, F., Nosenzo, D., Toussaert, S., and Abeler, J. (2020). Acceptability of app-based contact tracing for covid-19: Cross-country survey study. *JMIR mHealth and uHealth*, 8.

Aria, M. and Cuccurullo, C. (2017). bibliometrix: An r-tool for comprehensive science mapping analysis. *Journal of Informetrics*, 11.

Arksey, H. and O'Malley, L. (2005). Scoping studies: towards a methodological framework. *International journal of social research methodology*, 8(1):19–32.

Ausín, T. and Martínez, M. B. A. (2020). Ethics and health data protection in pandemics: A reference to the case of applications for contact tracking. *Enrahonar*, 65.

Bassi, A., Arfin, S., John, O., and Jha, V. (2020). An overview of mobile applications (apps) to support the coronavirus disease 2019 response in india. *Indian Journal of Medical Research*, 151.

Bhatia, A., Matthan, R., Khanna, T., and Balsari, S. (2020). Regulatory sandboxes: A cure for mhealth pilotitis? *Journal of medical Internet research*, 22(9):e21276.

Borra, S. (2020). Covid-19 apps: Privacy and security concerns. *SpringerBriefs in Applied Sciences and Technology*.

Cioffi, A., Lugi, C., and Cecannecchia, C. (2020). Apps for covid-19 contact-tracing: Too many questions and few answers. *Ethics, Medicine and Public Health*, 15.

Collado-Borrell, R., Escudero-Vilaplana, V., Villanueva-Bueno, C., Herranz-Alonso, A., and Sanjurjo-Saez, M. (2020). Features and functionalities of smartphone apps related to covid-19: Systematic search in app stores and content analysis. *Journal of Medical Internet Research*, 22.

Davalbhakta, S., Advani, S., Kumar, S., Agarwal, V., Bhoyar, S., Fedirko, E., Misra, D. P., Goel, A., Gupta, L., and Agarwal, V. (2020). A systematic review of smartphone applications available for corona virus disease 2019 (covid19) and the assessment of their quality using the mobile application rating scale (mars). *Journal of Medical Systems*, 44.

Editorial (2020). Covid-19 digital apps need due diligence. *Nature*, 580.

Galloway, K. (2020). The covid cyborg: Protecting data status. *Alternative Law Journal*, 45.

Goggin, G. (2020). Covid-19 apps in singapore and australia: reimagining healthy nations with digital technology. *Media International Australia*, 177.

Hoffman, A. S., Jacobs, B., van Gastel, B., Schraffenberger, H., Sharon, T., and Pas, B. (2020). Towards a seamful ethics of covid-19 contact tracing apps? *Ethics and Information Technology*.

Hsu, J. (2020). The dilemma of contacttracing apps: Can this crucial technology be both effective and private? *IEEE Spectrum*, 57.

Jahnel, T., Kernebeck, S., Böbel, S., Buchner, B., Grill, E., Hinck, S., Ranisch, R., Rothenbacher, D., Schüz, B., Starke, D., Wienert, J., Zeeb, H., and Gerhardus, A. (2020). Contact-tracing-apps als unterstützende maßnahme bei der kontaktpersonennachverfolgung von covid-19. *Das Gesundheitswesen*, 82.

Joo, J. and Shin, M. M. (2020). Resolving the tension between full utilization of contact tracing app services and user stress as an effort to control the covid-19 pandemic. *Service Business*, 14.

Kaspar, K. (2020). Motivations for social distancing and app use as complementary measures to combat the covid-19 pandemic: Quantitative survey study. *Journal of Medical Internet Research*, 22.

Kitchin, R. (2020). Civil liberties or public health, or civil liberties and public health? using surveillance technologies to tackle the spread of covid-19. *Space and Polity*.

Klar, R. and Lanzerath, D. (2020). The ethics of covid-19 tracking apps – challenges and voluntariness. *Research Ethics*, 16.

Klingwort, J. and Schnell, R. (2020). Critical limitations of digital epidemiology: Why covid-19 apps are useless. *Survey Research Methods*, 14.

Liang, F. (2020). Covid-19 and health code: How digital platforms tackle the pandemic in china. *Social Media and Society*, 6.

Lobato, L. L., Bittar, T. J., Neto, P. A. d. M. S., Machado, I. D. C., De Almeida, E. S., and MEIRA, S. R. D. L. (2013). Risk management in software product line engineering: a mapping study. *International Journal of Software Engineering and Knowledge Engineering*, 23(04):523–558.

Lucivero, F., Hallowell, N., Johnson, S., Prainsack, B., Samuel, G., and Sharon, T. (2020). Covid-19 and contact tracing apps: Ethical challenges for a social experiment on a global scale. *Journal of Bioethical Inquiry*.

Mbunge, E. (2020). Integrating emerging technologies into covid-19 contact tracing: Opportunities, challenges and pitfalls. *Diabetes and Metabolic Syndrome: Clinical Research and Reviews*, 14.

Michael, K. and Abbas, R. (2020). Behind covid-19 contact trace apps: The google-apple partnership. *IEEE Consumer Electronics Magazine*, 9.

MIT, T. R. (2020). Google spreadsheet listing covid tracing tracker. *Available online: http://bit.ly/3ilFt6R (last cited: [17/01/2021])*.

Morley, J., Cowls, J., Taddeo, M., and Floridi, L. (2020). Ethical guidelines for covid-19 tracing apps. *Nature*, 582.

Nanni, M., Andrienko, G., Barabàsi, A. L., Boldrini, C., Bonchi, F., Cattuto, C., Chiaromonte, F., Comandé, G., Conti, M., Coté, M., Dignum, F., Dignum, V., Domingo-Ferrer, J., Ferragina, P., Giannotti, F., Guidotti, R., Helbing, D., Kaski, K., Kertesz, J., Lehmann, S., Lepri, B., Lukowicz, P., Matwin, S., Megías, D., Monreale, A., Morik, K., Oliver, N., Passarella, A., Passerini, A., Pedreschi, D., Pentland, A., Pianesi, F., Pratesi, F., Rinzivillo, S., Ruggieri, S., Siebes, A., Torra, V., Trasarti, R., Hoven, J. V. D., and Vespignani, A. (2020). Give more data, awareness and control to individual citizens, and they will help covid-19 containment. *Transactions on Data Privacy*, 13.

Otoya-Tono, A. M., García-Chabur, M. A., Jaramillo-Moncayo, C., and Mahecha, Á. M. C. (2020). Covid-19: Generalidades, comportamiento epidemiológico y medidas adoptadas en medio de la pandemia en colombia. *Acta de Otorrinolaringología & Cirugía de Cabeza y Cuello*, 48(1):93–102.

Parker, M. J., Fraser, C., Abeler-Dörner, L., and Bonsall, D. (2020). Ethics of instantaneous contact tracing using mobile phone apps in the control of the covid-19 pandemic. *Journal of Medical Ethics*, 46.

Ramakrishnan, A. M., Ramakrishnan, A. N., Lagan, S., and Torous, J. (2020). From symptom tracking to contact tracing: A framework to explore and assess covid-19 apps. *Future Internet*, 12.

Rizzo, E. (2020). Covid-19 contact tracing apps: the 'elderly paradox'. *Public Health*, 185.

Rowe, F. (2020). Contact tracing apps and values dilemmas: A privacy paradox in a neo-liberal world. *International Journal of Information Management*, 55:102178.

Rowe, F., Ngwenyama, O., and Richet, J. L. (2020). Contact-tracing apps and alienation in the age of

covid-19. *European Journal of Information Systems*, 29.

Scassa, T. (2021). Covid-19 contact tracing: From local to global and back again. *International Journal of E-Planning Research*, 10.

Sharma, S., Singh, G., Sharma, R., Jones, P., Kraus, S., and Dwivedi, Y. K. (2020). Digital health innovation: Exploring adoption of covid-19 digital contact tracing apps. *IEEE Transactions on Engineering Management*.

Trang, S., Trenz, M., Weiger, W. H., Tarafdar, M., and Cheung, C. M. (2020). One app to trace them all? examining app specifications for mass acceptance of contact-tracing apps. *European Journal of Information Systems*, 29.

Urbaczewski, A. and Lee, Y. J. (2020). Information technology and the pandemic: a preliminary multinational analysis of the impact of mobile tracking technology on the covid-19 contagion control. *European Journal of Information Systems*, 29.

Vitak, J. and Zimmer, M. (2020). More than just privacy: Using contextual integrity to evaluate the long-term risks from covid-19 surveillance technologies. *Social Media and Society*, 6.

Vokinger, K. N., Nittas, V., Witt, C. M., Fabrikant, S. I., and Wyl, V. V. (2020). Digital health and the covid-19 epidemic: An assessment framework for apps from an epidemiological and legal perspective. *Swiss Medical Weekly*, 150.

WHO, W. H. O. (2020). Who coronavirus disease (covid-19) dashboard. *Available online: https://covid19.who.int/ (last cited: [14/01/2021])*.

Woodhams, S. (2020). Covid-19 digital rights tracker. *Available online: http://bit.ly/3syOBJZ (last cited: [17/01/2021])*.

Yamamoto, K., Takahashi, T., Urasaki, M., Nagayasu, Y., Shimamoto, T., Tateyama, Y., Matsuzaki, K., Kobayashi, D., Kubo, S., Mito, S., Abe, T., Matsuura, H., and Iwami, T. (2020). Health observation app for covid-19 symptom tracking integrated with personal health records: Proof of concept and practical use study. *JMIR mHealth and uHealth*, 8.

Yasaka, T. M., Lehrich, B. M., and Sahyouni, R. (2020). Peer-to-peer contact tracing: Development of a privacy-preserving smartphone app. *JMIR mHealth and uHealth*, 8.