GAO

United States Government Accountability Office

Report to Congressional Addressees

September 2021

TECHNOLOGY ASSESSMENT

Exposure Notification

Benefits and Challenges of Smartphone Applications to Augment Contact Tracing

GAO-21-104622

GAO@100
A Century of Non-Partisan Fact-Based Work

The cover image displays a stylized depiction of the use of an exposure notification app by various individuals and an example of an exposure notification message.

Cover source: GAO. | GAO-21-104622

Highlights of GAO-21-104622, a report to congressional addressees

September 2021

Why GAO did this study

With the emergence and rapid global spread of COVID-19, smartphone apps have been developed to supplement manual contact tracing, which is a public health measure used to slow the spread of infectious disease.

GAO was asked to conduct a technology assessment of exposure notification apps. This report discusses (1) the benefits of exposure notification apps; (2) the current level of deployment in the U.S.; (3) challenges affecting their use; and (4) policy options that may help address these challenges for future use.

To address these objectives, GAO reviewed agency documentation, met with officials from several federal agencies, and conducted a review of technical and policy literature. GAO also interviewed representatives from companies involved in the development of exposure notification apps, public health organizations, federally funded research and development centers, and academic researchers. In addition, GAO analyzed information from a selection of states. GAO is identifying policy options in this report.

GAO received technical comments on a draft of this report from five federal agencies and five organizations included in the review, which it incorporated as appropriate.

View GAO-21-104622. For more information, contact Karen L. Howard at (202) 512-6888 or, howardk@gao.gov or Vijay A. D'Souza, at (202) 512-6240, dsouzav@gao.gov.

TECHNOLOGY ASSESSMENT

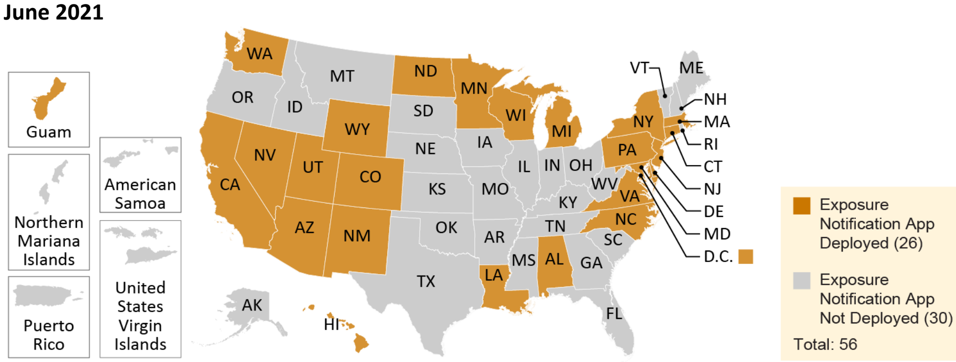
Exposure Notification

Benefits and Challenges of Smartphone Applications to Augment Contact Tracing

What GAO found

Exposure notification applications (apps)—which determine the proximity of users and notify people who have been in close contact with another user who was likely infectious—are expected to enhance the speed and reach of contact tracing and help slow the spread of infectious diseases such as COVID-19. As of June 2021, almost half (26/56) of U.S. states, territories, and the District of Columbia had deployed an app for COVID-19, all using a system developed jointly by Google and Apple (see figure). In the absence of a national app, states independently launched apps, resulting in a staggered rollout over 10 months beginning in August 2020.

Map of deployment of exposure notification apps by U.S. states and territories, as of June 2021



Source: GAO analysis of data from Goggle, Apple, the Association of Public Health Laboratories, and other sources, including state-level public health departments' websites. | GAO-21-104622

Reported app development costs for selected states varied, ranging from no cost (provided by a nonprofit organization) to $700,000. Marketing costs for selected states ranged from $380,000 to $3.2 million. Reported app download levels in the selected states ranged from 200,000 to more than 2 million, as of June 2021.

GAO identified several challenges limiting app use and the ability of states and others to determine whether the apps were effective:

Accuracy of measurements	Technical limitations to measuring distance and exposure can result in inaccurate exposure notifications.
Privacy and security concerns	The public may lack confidence that its privacy is being protected, in part, due to a lack of independent privacy and security assessments and a lack of federal legal protections.
Adoption	States have faced challenges attracting public interest in downloading and using an exposure notification app.
Verification code delays	States faced challenges in promptly providing people who tested positive for COVID-19 with a verification code necessary to notify other close contacts of potential exposure using the app.
Evidence of effectiveness	Limited data are available to evaluate the effectiveness of the apps.

Source: GAO. | GAO-21-104622

GAO developed the following four policy options that could help address challenges related to exposure notification apps. The policy options identify possible actions by policymakers, which may include Congress, other elected officials, federal agencies, state and local governments, and industry. See below for details of the policy options and relevant opportunities and considerations.

Policy Options to Help Address Challenges of Exposure Notification Apps for Future Use

	Opportunities	Considerations
Research and Development (report page 41) Policymakers could promote research and development to address technological limitations.	• Research on technological limitations could help increase accuracy, encouraging users to download and use the apps. • Research on technologies and architectures other than those used by U.S. states could lead to improvements. • Partnerships with technology companies could spur innovation and help with integrating improvements.	• The research needed may be costly. • Improvements may not be cost-effective, since existing apps may already be sufficiently accurate. • Research may result in apps that are not functional for the next pandemic, since the current apps were developed for COVID-19.
Privacy and Security Standards and Practices (report page 42) Policymakers could promote uniform privacy and security standards and practices for exposure notification apps.	• Uniform standards and best practices could help address real and perceived risks to the public's data, potentially increasing adoption. • Standards developed by a broad coalition of stakeholders could increase the likelihood of stakeholder agreement and buy-in.	• Policymakers would need to balance the need for privacy and security with the costs of implementing standards and practices. • Implementation of privacy requirements may need to be flexible, since jurisdictions could use different approaches. • Standards and practices could be challenging to oversee and enforce.
Best Practices (report page 43) Policymakers could promote best practices for approaches to increasing adoption and to measure the effectiveness of exposure notification apps.	• Best practices could help authorities better promote app adoption. • Best practices could help state public health authorities by providing information on procedures and potential approaches for distributing verification codes in a timely manner. • Best practices could help public health authorities establish a more rigorous way to measure the extent of app use and any resulting improvements in notifying exposed people.	• Best practices could require consensus from many public- and private-sector stakeholders, which can be time- and resource-intensive. • Current best practices may have limited relevance to a future pandemic. • In some cases, stakeholders may lack sufficient information or the experience to develop best practices.
National Strategy (report page 44) Policymakers could collaborate to enhance the pandemic national strategy and promote a coordinated approach to the development and deployment of exposure notification apps.	• Enhanced national coordination that builds on the underlying infrastructure and lessons learned from COVID-19 could prompt faster deployment of apps in the future. • A future national marketing campaign with cohesive and coherent messaging could result in wider adoption. • Policymakers could recommend a national app that public health authorities could decide to use based on their individual needs. A national app could add more functions by integrating exposure notification capabilities with test scheduling and vaccine delivery coordination.	• A coordinated national approach would likely have associated costs and require sustained funding during the pandemic. • Coordination of groups with divergent perspectives and interests may pose challenges to defining outcomes, measuring performance, and establishing a leadership approach. • It is unclear whether potential users would be more or less likely to trust a national exposure notification app than one developed by a state government.

Source: GAO. | GAO-21-104622

Table of Contents

Introduction 1

1 Background 4

1.1 COVID-19 4

1.2 Manual contact tracing for COVID-19 4

1.3 Roles of states, federal agencies, and other stakeholders 6

2 Benefits and Design of Exposure Notification Apps 9

2.1 Exposure notification apps are expected to provide enhanced speed and reach 9

2.2 How exposure notification apps work 10

2.3 Apps can use either a centralized, decentralized, or hybrid system to manage data 12

2.4 States are widely using the Google and Apple Exposure Notifications system 14

3 Deployment and Adoption of Exposure Notification Apps 18

3.1 About half of the states have deployed an exposure notification app 18

3.2 About half of the states use a customized app 21

3.3 States reported that app development time and cost varied based on several factors 25

3.4 Officials reported varying download levels and use 26

4 Challenges Associated with Exposure Notification Apps 27

4.1 Accuracy of measurements 27

4.2 Privacy and security concerns 28

4.3 Adoption and use of apps 31

4.4 Verification code delays 32

4.5 Limited evidence of effectiveness 33

5 Policy Options That Could Help Address Challenges for Future Use 41

5.1 Policy option: Research and development 41

5.2 Policy option: Privacy and security standards and best practices 42

5.3 Policy option: Best practices to measure effectiveness 43

5.4 Policy option: Enhance the national strategy 44

6 Agency and Expert Comments 46
Appendix I: Objectives, Scope, and Methodology 47
Appendix II: Exposure Notification App Adoption Rates for Selected U.S. States 51
Appendix III: GAO Contacts and Staff Acknowledgments 54

Abbreviations

APHL	Association of Public Health Laboratories
BLE	Bluetooth Low Energy
CDC	Centers for Disease Control and Prevention
COVID-19	Coronavirus Disease 2019
DHS	Department of Homeland Security
FCC	Federal Communications Commission
FTC	Federal Trade Commission
GPS	Global Positioning System
HHS	Health and Human Services
NIH	National Institutes of Health
NIST	National Institute of Standards and Technology
QR	quick response
WHO	World Health Organization

U.S. GOVERNMENT ACCOUNTABILITY OFFICE
441 G St. N.W.
Washington, DC 20548

Introduction

September 9, 2021

Congressional Addressees

For more than a century, public health authorities have used contact tracing to track and limit the spread of infectious diseases. Manual contact tracing involves interviewing infected people to identify others they have been in contact with, notifying those contacts that may have been exposed, and advising the infected individual and contacts to take appropriate measures.

Manual contact tracing can be effective, but it has limitations. Specifically, it is a resource-intensive process, and it is most effective during the early stage of an outbreak, when case numbers tend to be lower, or during phases with fewer cases.[1] In addition, its effectiveness relies, in part, on prompt and complete identification of individuals and notification of contacts, which could be difficult with a rapidly spreading disease. Other limitations of manual contact tracing include the reliance on human recall of contacts and movements (which can be prone to error), and the inability to identify strangers. Further, people may not be forthcoming in sharing information about their contacts.

With the emergence and rapid spread of the highly infectious Coronavirus Disease 2019 (COVID-19), digital contact tracing technologies have been developed to supplement manual contact tracing and help address its limitations. One such technology is a type of application (app) developed for use on a smartphone.[2] Referred to as an exposure notification app,[3] it is intended to be used to notify a smartphone user who has been in close contact with another user who later tested positive for COVID-19.[4] This type of app is intended to reduce transmission by notifying potentially exposed people faster than manual contact tracing, including contacts the infected person may not have known.

---

[1]Center for Infectious Disease Research and Policy, *COVID-19: the CIDRAP Viewpoint,* (Minneapolis, Minn.: University of Minnesota, June 2, 2020).

[2]An estimated 85 percent of adults in the U.S. own a smartphone, according to a survey conducted by the Pew Research Center. However, this decreases to an estimated 61 percent for people 65 and older. In addition, the rate varies based on other factors, including income level and whether a person lives in an urban or rural area. This estimate was based on a survey of U.S. adults, conducted between Jan. 25 and Feb. 8, 2021. See Pew Research Center, *Mobile Fact Sheet*, (Washington, D.C.: Apr. 7, 2021), accessed July 1, 2021, https://www.pewresearch.org/internet/fact-sheet/mobile.

[3]An exposure notification app can include both software that a user downloads to use on a smartphone, or a function built into the phone's operating system that can be activated by users.

[4]While contact tracers have previously used smartphone apps, including for data entry, we are unaware of any exposure notification apps in public use prior to the COVID-19 pandemic.

In July 2020, we issued a Science & Tech Spotlight overview of exposure notification app technology.[5] Since then, there has been an increase in the development and use of these apps. You asked us to conduct an assessment of these technologies. This report discusses (1) the benefits and design of exposure notification apps, (2) the current level of deployment in the U.S., (3) challenges affecting their use, and (4) policy options that could help address key challenges for future use.

To address all of these objectives, we reviewed documentation and met with officials from selected federal agencies involved in providing guidance, funding research, and directing other efforts related to exposure notification apps. In addition, we interviewed representatives from entities involved in the development of exposure notification apps; public health organizations; federally funded research and development centers; academic researchers; and nongovernmental organizations. We also conducted a review of literature discussing exposure notification apps, including their benefits, design, and challenges, as well as relevant policy options.

To identify the current level of deployment, we developed an inventory of exposure notification apps that had been deployed by U.S. states, territories, and the District of Columbia (hereafter referred to as states) as of June 2021. States that had an app in a pilot phase at the time of our review were included the category of "states that had not deployed an app as of June 2021."

To obtain additional information associated with the development and use of these apps, we interviewed state public health officials from a non-generalizable sample of nine states that had deployed an exposure notification app as of January 1, 2021: Alabama, Colorado, Connecticut, Minnesota, Nevada, North Carolina, Pennsylvania, Virginia, and Washington. We also reached out to two other states (Louisiana and Utah) that deployed apps in the later stages of our evidence collection and received written feedback to structured questions about the status of their efforts to deploy an app, their rates of adoption, and other topics. We selected the sample of nine states to obtain a range of views, based on factors such as deployment date, geographical distribution, number of COVID-19 cases, and app developer. Because the selection was based on a non-generalizable sample, the results were not used to make inferences about all states that had deployed an app. In addition to our interviews with officials from the selected states, we conducted a review of each of the selected states apps, including the key functions, features, and privacy use policies for those apps.

To obtain perspectives from states that had not deployed an app, we collected information from a non-generalizable selection of seven states that had not deployed an app at the time of our review (Montana, Nebraska, Oregon, Rhode Island, South Carolina, Texas, and West Virginia).

[5]GAO, *Science & Tech Spotlight: Contact Tracing Apps*, GAO-20-666SP (Washington, D.C.: July 28, 2020). While the terms exposure notification apps and contact tracing apps have been used to describe these technologies, we will use the term exposure notification apps in this review.

For these states, we conducted an interview with officials from one state and obtained written responses to a semi-structured set of questions for the other six.

We identified policy options that may address the identified challenges based on our literature review and interviews. We assessed each policy option by identifying potential benefits and considerations of implementing them, as identified over the course of our review. See appendix I for a detailed description of our objectives, scope, and methodology.

We conducted our work from November 2020 to September 2021 in accordance with all sections of GAO's Quality Assurance Framework that are relevant to technology assessments. The framework requires that we plan and perform the engagement to obtain sufficient and appropriate evidence to meet our stated objectives and to discuss any limitations to our work. We believe that the information and data obtained, and the analysis conducted, provide a reasonable basis for any findings and conclusions in this product.

1 Background

1.1 COVID-19

The outbreak of COVID-19 was first reported on December 31, 2019, in Wuhan, China.[6] In the weeks that followed, the virus quickly spread around the globe. On January 31, 2020, the Secretary of Health and Human Services declared a public health emergency for the U.S., retroactive to January 27, which followed a World Health Organization (WHO) declaration on January 30 that the outbreak constituted a public health emergency of international concern. On March 11, 2020, WHO characterized the COVID-19 outbreak as a global pandemic due to its levels of spread and its severity. COVID-19 is highly contagious and may be spread by people who are not showing symptoms (i.e., "asymptomatic") or before symptoms appear ("pre-symptomatic").

More than a year later, as we have previously reported, the pandemic has resulted in catastrophic loss of life and substantial damage to the global economy, and to the stability and security of our nation.[7] In the U.S., there have been more than 596,000 reported deaths[8] and 32 million reported confirmed and probable cases as of July 2021.[9] In addition, despite strides made in getting people vaccinated, the threat of variants is growing, including evidence of increased transmissibility. As a result, uncertainty about the future of the COVID-19 pandemic remains.

1.2 Manual contact tracing for COVID-19

Contact tracing is a key component in controlling the transmission and spread of infectious diseases, according to the Centers for Disease Control and Prevention (CDC).[10] Contact tracing is intended to separate the people who have (or may have) an infectious disease from those who do not and provide information on other measures the potentially exposed contacts should take, such as being tested for the disease or self-isolating. Together, the test, trace, and isolate strategy is part of the

---

[6]This disease is caused by SARS-CoV-2 (Severe Acute Respiratory Syndrome, Coronavirus 2).

[7]GAO, *COVID-19: Key Insights from the GAO's Oversight of the Federal Public Health Response*, GAO-21-396T (Washington, D.C.: Feb. 24, 2021).

[8]CDC's National Center for Health Statistics COVID-19 death counts in the U.S. are based on provisional counts from death certificate data, which do not distinguish between laboratory-confirmed and probable COVID-19 deaths. Provisional death counts are incomplete due to an average delay of 2 weeks (a range of 1–8 weeks or longer) for death certificate processing. Data include deaths occurring from January 2020 through the week ending on July 3, 2021. Centers for Disease Control and Prevention, *National Center for Health Statistics,* (Atlanta, Ga.), accessed July 7, 2021, https://www.cdc.gov/nchs/nvss/vsrr/covid19/index.htm.

[9]Data on COVID-19 cases in the U.S. are based on aggregate case reporting to the Centers for Disease Control and Prevention, *COVID Data Tracker,* (Atlanta, Ga.), accessed July 7, 2021, https://covid.cdc.gov/covid-data-tracker/#datatracker-home, and include probable and confirmed cases as reported by states and jurisdictions. Centers for Disease Control and Prevention (CDC) COVID-19 counts are subject to change due to delays or updates in reported data from states and territories. According to CDC, the actual number of COVID-19 cases is unknown for a variety of reasons, including that people who have been infected may not have been tested or may not have sought medical care.

[10]Centers for Disease Control and Prevention, *Operational Consideration for Adapting a Contact Tracing Program to Respond to the COVID-19 Pandemic in non-US Settings*, (Atlanta, Ga.: June 23, 2021).

broader effort to limit the transmission of infectious diseases such as COVID-19.

Contact tracers are the people who manually trace the contacts of each person who has tested positive for COVID-19. Contact tracers begin the process by interviewing the person with the positive test result in order to identify others whom that person might have contacted. Next, the tracer advises the person and the contacts to take containment measures (e.g., a 14-day quarantine for COVID-19), and coordinates or provides information on any needed care, testing recommendations, and resources.[11]

For COVID-19, CDC defines a close contact as anyone who has been within 6 feet of an infected person for a total of 15 minutes or more over a 24-hour period (for example, three individual 5-minute exposures for a total of 15 minutes).[12] According to CDC, infected persons can spread COVID-19 starting from 48 hours (or 2 days) before they have symptoms or test positive for COVID-19.

In a public health emergency such as the COVID-19 pandemic, it is critical that each state has a sufficient workforce of contact tracers in order to contain the disease. Although state and local public health agencies typically maintain an existing capacity to conduct contact tracing for infectious diseases, this capacity is generally sufficient only to respond to relatively small or isolated outbreaks.

Contact tracing is resource intensive, because, as cases increase, the contact tracer will need more time to contact all potentially exposed persons. Hence, more and more tracers will be needed to ensure comprehensive contact tracing of all diagnosed cases and potentially exposed persons. The particular features of the COVID-19 pandemic—asymptomatic persons and the ability to spread rapidly—require a significantly large workforce of contact tracers. According to the National Association of County and City Health Officials, the benchmark rate is 30 contact tracers per 100,000 people. This equates to about 98,460 contact tracers needed to cover the entire U.S. population.[13] According to CDC, state health departments reported a total of 51,855 employed contact tracers for the month of December 2020, which was about one month before the peak of reported new cases in the U.S.[14]

To supplement the capabilities of manual contact tracing, several states have used smartphone apps. These apps include those that help people monitor their COVID-19

[11]Consistent with CDC guidance, except in certain circumstances, people who have been in close contact with someone who has COVID-19 should quarantine. However, people who have been fully vaccinated and people who were previously diagnosed with COVID-19 within the last 3 months may not need to quarantine.

[12]See Centers for Disease Control and Prevention, "Appendices," *COVID-19,* (Atlanta, Ga.: Updated July 2, 2021), accessed July 2, 2021, https://www.cdc.gov/coronavirus/2019-ncov/php/contact-tracing/contact-tracing-plan/appendix.html#contact.

[13]National Association of County and City Health Officials, *Position Statement: Building COVID-19 Contact Tracing Capacity in Health Departments to Support Reopening American Society Safely (*Washington, D.C.: Apr. 16, 2020).

[14]This number represents a best estimate for a 1-month snapshot and may not include contact tracers employed at the local health department or community level, according to CDC documentation. Data are reported monthly, and estimates will continue, and be updated regularly, according to CDC. We used the reported estimates from December 2020 to illustrate capacity just before the peak cases observed in January 2021.

symptoms, assist people in recalling the places they had visited when providing that information to a contact tracer, and exposure notification apps.[15]

1.3 Roles of states, federal agencies, and other stakeholders

Various entities have a role in the deployment and use of exposure notification apps within the U.S. These entities include states, federal agencies, and other stakeholders, such as national public health organizations and organizations involved in research and development of the apps.

States

In the U.S., public health authorities at the state, territorial, and local levels plan and coordinate pandemic response actions within their jurisdictions. In addition, these authorities generally lead contact tracing efforts, including the implementation of related technologies, such as exposure notification apps.

Federal agencies

Federal agencies—including CDC, the Department of Homeland Security (DHS), the National Institutes of Health (NIH), and the National Institute of Standards and Technology (NIST)—have taken various steps to assist states in the development and use of exposure notification apps, including issuing guidance, distributing funds to states, and funding research.

Specifically, in May 2020 and December 2020, CDC issued two guidance documents on digital contact tracing tools, which included discussion of exposure notification apps.[16] The guidance is intended to provide health departments with minimum and preferred characteristics of the apps, including those for contact notification and data security.[17] In addition, CDC distributes funds to states—through established mechanisms such as its Epidemiology and Laboratory Capacity for Prevention and Control of Emerging Infectious Diseases cooperative agreement, which currently provides funds to 64 jurisdictions to detect, prevent, and respond to the growing threats posed by infectious diseases, including for the development and use of exposure notification apps, according to

[15]For example, in April 2020, Utah deployed an app which allowed residents to check their symptoms, and privately share a subset of their location information with public health officials to aid in the contact tracing process. In summer 2020, Utah disabled the location–based services in this app.

[16]Centers for Disease Control and Prevention, *Preliminary Criteria for the Evaluation of Digital Contact Tracing Tools for COVID-19*, version 1.2 (Atlanta, Ga.: May 17, 2020); and *Guidelines for the Implementation and Use of Digital Tools to Augment Traditional Contact Tracing*, version 1.0 (Atlanta, Ga: Dec. 15, 2020).

[17]These characteristics included that the apps should enable health departments to define different exposure risk levels used to identify contacts based on how close and how long their exposure was and to require user consent before their data are shared with a health department.

CDC documentation.[18] (See ch. 3 for additional information on uses of this funding.)

CDC has also funded research on exposure notification apps, including research performed by the Massachusetts Institute of Technology's Lincoln Laboratory, to examine barriers to adoption and the efficacy of the underlying technologies used by various apps. Further, CDC officials stated that the agency has provided ongoing support and consultation to states interested in implementing exposure notification apps. For example, since early August 2020, CDC has coordinated with Lincoln Laboratory to host meetings with state public health authorities where they can discuss issues related to app development and deployment.

In addition, DHS's Science and Technology Directorate provided funding to two projects through its Silicon Valley Innovation Program.[19] These projects are intended to develop criteria the apps can be tested against and to enable the capability to test the apps using the criteria. According to DHS officials, they expect that these projects will be completed in the next 2 years. NIH has also funded various projects related to contact tracing tools.[20]

In early 2020, NIST began work on a project, which is currently ongoing, to study and develop exposure notification systems with strong privacy and cybersecurity protocols.[21] As a part of this project, NIST held an event in June 2020 to help facilitate research aimed at improving the performance of these kinds of apps. Further, in January 2021, NIST held a workshop on challenges associated with exposure notification apps.

Other stakeholders

National public health organizations have issued guidance and provided other support to state public health authorities to assist in the development and deployment of exposure notification apps. These organizations include the Association of Public Health Laboratories (APHL), Association of State and Territorial Health Officials, Council of State and Territorial Epidemiologists, National Association of County and City Health Officials, Linux Foundation Public Health, the Public Health Informatics Institute, and others. Other key stakeholders include entities involved in the research and development of exposure

[18]The 64 jurisdictions receiving awards under the Epidemiology and Laboratory Capacity for Prevention and Control of Emerging Infectious Diseases cooperative agreements include all 50 states, several large metro areas, and U.S. territories and affiliates. A full list of recipients is provided on the Centers for Disease Control and Prevention's website. See Centers for Disease Control and Prevention, National Center for Emerging and Zoonotic Infectious Diseases, Division of Preparedness and Emerging Infections, *Recipients, Project Officers, and Jurisdictional Assignment Listing*, (Atlanta, Ga.: last reviewed June 16, 2021), accessed June 30, 2021, https://www.cdc.gov/ncezid/dpei/elc/advisor-list.html.

[19]DHS intends for this program to find new technologies that strengthen national security.

[20]These projects included tools to identify businesses and hot spots visited by people with COVID-19 and development of a digital health pass to enable businesses to verify health credentials.

[21]A system (or protocol) provides a framework that determines the function of a particular software application, like an app on a smartphone.

notification apps or analysis of their performance. Specifically, researchers, organizations, and technology companies have played a key role in the design of the systems used by exposure notification apps.[22]

In May 2020, Google and Apple—the two primary developers of operating systems for smartphones—collaborated on the development of an exposure notification system used by the states discussed later in the report. According to Google and Apple, they developed this system to help governments and the global community slow the spread of the COVID-19 pandemic. In addition, Google and Apple collaborated with Microsoft and APHL to establish and host servers to facilitate the system. Further, Google and Apple collaborated with the MITRE Corporation to deploy the Exposure Notification Private Analytics portal, which provides public health authorities with data on the performance of the states' apps. This effort involves several other partners, including the Internet Security Research Group and NIH.

[22]These include, for example, the TCN Coalition and Massachusetts Institute of Technology Pact developed systems—referred to as the Temporary Contact Numbers Protocol, or TCN Protocol; and the Private Automated Contact Tracing (PACT) protocol, respectively.

2 Benefits and Design of Exposure Notification Apps

Exposure notification apps are intended to automate and augment the manual contact tracing process, with enhanced speed and reach being among the expected benefits, according to scientific literature, state officials, federal agency documents, and representatives of stakeholder organizations we interviewed. They work by using proximity detection to determine when two smartphone users are in close contact, then notifying all contacts of a user who later reports a positive test result for COVID-19. The apps can use a centralized, decentralized, or hybrid system to collect, store, and manage data. Many states within the U.S. are using apps based on a decentralized system that was developed jointly by Google and Apple.

2.1 Exposure notification apps are expected to provide enhanced speed and reach

Exposure notification apps are expected to provide two key benefits—speed and reach. Specifically, they are expected to allow for more timely identification and notification of contacts and greater (more complete) coverage of contacts, according to the majority of the selected states, CDC documentation, and publications that we reviewed.

Speed. Apps are expected to allow for faster identification and notification of contacts. After a positive test result is received, apps automate the process of identifying and notifying contacts. This automation can lead to faster notification, which in turn can lead to faster changes in individual behavior aimed at helping slow disease transmission, namely testing and quarantine, according to selected studies.[23]

Reach. Apps are also expected to provide more complete and faster identification of contacts because, unlike manual contact tracing, they do not rely on a person's memory to identify the people they came into contact with, according to CDC documents. In addition, according to a Pew Research Center report, 41 percent of Americans asked about their views on speaking with a public health official reported that they are unlikely to talk with contact tracers. The report also noted that younger adults, those with lower incomes, and those with less formal education are especially unlikely to engage with manual contact tracers.[24] Apps may provide a way to increase coverage of these populations. In addition, apps can reach people even

[23]John Hopkins University and Association of State and Territorial Health Officials, *A National Plan to Enable Comprehensive COVID-19 Case Finding and Contact Tracing in the US* (Baltimore, Md.: Johns Hopkins University, Apr. 10, 2020), Massachusetts Institute of Technology Lincoln Laboratory, *Realizing the Promise of Automated Contact Tracing Technology to Control the Spread of COVID-19: Recommendations for Smartphone App Deployment, Use, and Iterative Assessment* (Cambridge, Mass.: Massachusetts Institute of Technology, Oct. 29, 2020), and J.A. Moreno Lopez et al., "Anatomy of Digital Contact Tracing: Role of Age, Transmission, Setting, Adoption, And Case Detection," *Science Advances,* vol. 7, no. 15 (2020): eabd8750.

[24]Pew Research Center, *The Challenges of Contact Tracing as U.S. Battles COVID-19*, (last updated Oct. 30, 2020), accessed July 2, 2021, https://www.pewresearch.org/fact-tank/2020/10/30/key-findings-about-americans-views-on-covid-19-contact-tracing/.

when manual contact tracing resources are limited or overwhelmed.

2.2 How exposure notification apps work

Exposure notification apps use proximity detection to determine whether two app users are in close contact. The app then notifies a person if they had been in close contact with another user who was likely infectious at the time, and who voluntarily confirmed their diagnosis in the app. Proximity detection involves a series of automated actions that determine the proximity of two persons, notify them of potential exposure, and provide guidance in the case of exposure.

The proximity detection steps are described more fully here.

- An exposure notification app periodically broadcasts messages (referred to as encounter messages) using a wireless radio transmission technology—Bluetooth Low Energy (BLE)[25]—that contain, among other things, a random identifier and the strength of the signal sent (i.e., transmitted power).[26] Any other phone that has the same or similar app installed and is in range of the user's signal can receive and store these encounter messages. The distance between two phones can be estimated by comparing the strength of the BLE signal when it was sent with its strength when it is received.[27]
- If one or more of the messages later turns out to have been from a contact who tested positive for COVID-19, a central server or a user's smartphone analyzes the encounter message to determine whether the user's risk of exposure exceeds a predetermined threshold. The risk analysis includes factors such as the time spent at various distances and when the contact occurred in relation to when the contact was most infectious.[28]

The formula used to calculate the level of risk, including the specific risk factors, can be set by the public health agency. The assessment generally involves determining whether the encounter meets the CDC's definition of a close contact (i.e., at least 15 minutes within 6 feet within 24 hours). The apps do not consider other factors that affect the risk of infection. For example, they do not consider whether the users were wearing masks, or whether the encounter occurred in a well ventilated location (e.g., indoors or outdoors).

[25]BLE is a wireless radio transmission technology with a range of around 30 feet. BLE started to be included in smartphones in 2011, and is now included on most smartphones to enable communication between devices, such as smart watches and wireless headphones.

[26]To help preserve user privacy and to limit the ability to track the movements of other users, the random identifiers are changed on a periodic basis (e.g., every 10 minutes). Further, the identifiers do not reveal any personal information about other users.

[27]The BLE signal will weaken as the distance between two smartphones increases. The strength of the signal when it is received is referred to as a received signal strength indication measurement.

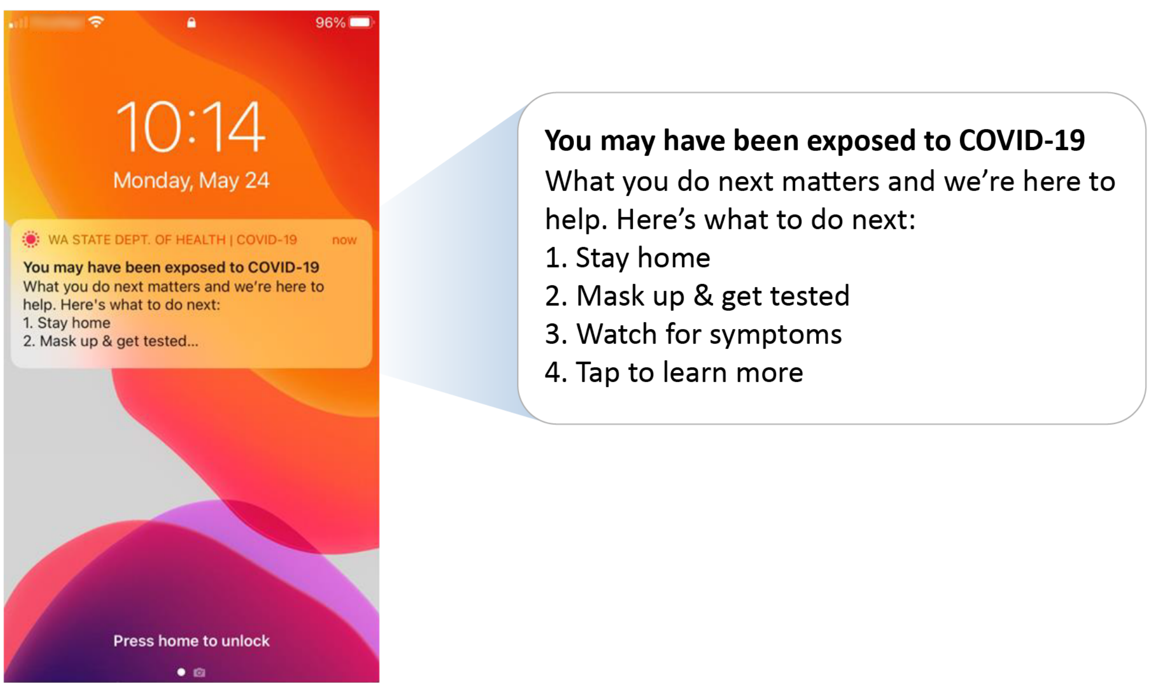
[28]This can be determined based on when the person first had symptoms or was tested.

If a user's risk of exposure exceeds the risk threshold, the user receives an exposure notification from the app.[29] The exposure notification can also include other information, such as when the exposure occurred and the next steps the person should take, such as getting tested, monitoring symptoms, and self-quarantining. See figure 1 for an example of an exposure notification message.

The distance measured between two phones using BLE is only an estimate, and its accuracy can be affected by various factors. See section 4.1 for additional discussion of factors affecting the accuracy of measurements and other potential technologies.

Location data can also be used instead of, or in addition to, the data gathered using the BLE messages. Location data are not currently used by U.S. states. However, other nations (e.g., Israel) have apps that use Global Positioning System (GPS) data to track and record a person's location, including the date and time.[30] Further, apps can track user locations by having the user scan a quick response (QR) code at a specific location (e.g., venue, restaurant).[31] The app then records the location, date,

Figure 1: Example of an exposure notification message



Source: GAO review of selected exposure notification apps: WA Notify - Washington Department of Health. | GAO-21-104622

[29]In certain systems, a public health provider could provide the notification in lieu of an app notification.

[30]Other methods to determine a smartphone's location include assisted-GPS, the triangulation of cell towers, and Wi-Fi access point identification.

[31]A QR code is a barcode with the ability to encode different types of information. Each location needs to have a unique QR code and it must be accessible (e.g., posted at the entrance to a building).

and time.[32] See figure 2 for an example of a QR code.

Figure 2: Example of a QR code

Source: GAO. | GAO-21-104622

A user's recent locations can be compared with a list of locations of people who have tested positive for COVID-19 to determine the risk of exposure.[33] However, GPS location estimates are only accurate within about a 16-foot radius outdoors. In addition, the accuracy decreases near buildings, bridges, and trees, and indoors or underground.[34] Thus, the location estimates may not always be reliable in determining whether two people were in close contact.

2.3 Apps can use either a centralized, decentralized, or hybrid system to manage data

Exposure notification apps can use a centralized, decentralized, or hybrid architecture for collecting, storing, and analyzing data.[35] The main difference between these types of architecture is the extent to which the information used to determine exposure is stored and analyzed on a central server or on an individual smartphone. These differences affect the privacy protections built into the system. A decentralized architecture may help preserve a user's privacy more than a centralized architecture. These types of architecture are described more fully here.

- In a centralized architecture, most of the data are stored on a central server, which also analyzes the data to determine which users may have been exposed. For example, the central server collects personal information as a part of users' registration and generates the random identifiers used for the encounter messages. A public health authority can access this information (including information on which users were in contact) and aggregate it to perform further analyses of the data to identify additional potential exposures and to identify potential surges in cases to help inform

[32] The app uses the phone's camera to scan the QR code.

[33] The list of locations from infected persons can also include locations obtained through manual contact tracing.

[34] National Coordination Office for Space-Based Positioning, Navigation, and Timing, *GPS Accuracy*, (Washington, D.C.: last update Apr. 22, 2020), accessed May 17, 2020, https://www.gps.gov/systems/gps/performance/accuracy.

[35] Data architecture is a framework that comprises of models, policies, rules, and standards that govern the collection, storage, arrangement, integration, and use of data in organizations.

broader mitigation and response efforts. The central server can also incorporate data from other sources, such as manual contact tracing (e.g., locations an infected person visited). However, storing data on a centralized server can also reveal potentially sensitive information to governmental organizations, or others who gain access to the server. An example of a centralized app is one used by the nation of Singapore, which it deployed in March 2020.

- In a decentralized architecture, most of the data are located on users' smartphones, with only limited data on a central server. Each user's device analyzes the data to determine whether an exposure has occurred. This approach may help preserve personal privacy; however, it also limits the data that are available to public health authorities for determining the effectiveness of the apps, informing contact tracing efforts, and identifying where infections may be occurring. For example, this architecture does not allow authorities to know who received an exposure notification.
- A hybrid architecture incorporates aspects of both architectures. Specifically, the random identifier generation for encounter messages remains decentralized (i.e., handled by user smartphones) to help preserve privacy, while the risk analysis and notifications are handled by the central server. Hybrid systems have been developed by researchers, but we are not aware of their use at a national or state level.

Table 1 provides a comparison of the different architectures, including how data are managed and the key advantages and disadvantages to each approach.

Table 1: Advantages and disadvantages of centralized, decentralized, and hybrid data architectures used in exposure notification apps

	Centralized	Decentralized	Hybrid
Where most information is stored	central server	smartphone device	smartphone device
Where random identifiers are generated	central server	smartphone device	smartphone device
Where exposure data are analyzed	central server	smartphone device	central server
Level of data access by public health authorities	higher	lower	moderate
Key advantages	Public health authorities can access data to perform analysis, identify additional exposure and potential surges, and inform response efforts.[a]	Seeks to preserve individual privacy by limiting data accessible to entities (e.g., public health authorities).	Seeks to preserve individual privacy and provides health authorities with useful data.
Key disadvantages	Data could reveal potentially sensitive information to public health authorities or other entities that gain access to the server.	Limits the data that are available to public health authorities for determining how well the app works and to inform response efforts.	Data could reveal potentially sensitive information to public health authorities or other entities that gain access to the server.

Source: Based on GAO review of technical and industry documentation. I GAO-21-104622

[a]The central server can also incorporate data from other sources, such as manual contact tracing (which can provide the location of an infected person among other things).

2.4 States are widely using the Google and Apple Exposure Notifications system

U.S. states with apps are using the Google and Apple Exposure Notifications system.[36] (See ch. 3 for additional information on deployment of apps by state public health authorities.) The Google Apple system was released in May 2020 as an application-programming interface to be used by public health authorities in developing and customizing their own exposure notification apps.

In September 2020, Google and Apple provided public health authorities with an additional option (referred to as the Express option), which was intended to make it easier for authorities to use the Google Apple system by removing the need for the authorities to build their own custom apps. In this option, Google developed an app for Android-based phones, and Apple deployed app-less functionality, such that a person can

[36]For the purposes of this report we refer to the Google and Apple Exposure Notifications system as the Google Apple system.

enable the system for their area (if available) through the settings on an iPhone.[37]

The Google Apple system uses BLE and a decentralized architecture. In this system, each user's app creates a temporary key (changes every 24 hours) that the app uses to generate random identifiers, and to encrypt information provided in the encounter messages. The app then exchanges a random identifier with other users' apps, and maintains a list of the encounter messages that the user has received. To help preserve the privacy of the users, the encounter messages do not include personal information or location data.

If the user tests positive for COVID-19, a public health authority uses a verification server to generate a verification code, and then sends the user the code to verify the positive test result. A user can then voluntarily input this code in the app to submit their recent temporary keys (e.g., prior 14 days) to a key server. If a user chooses not to input the code in the app, the user will not enable the notification of other recent close contacts who were also using the app of potential exposure.

Each exposure notification app periodically downloads the temporary keys from people who had recently tested positive from the key server and then compares it with its list of encounter messages. If there is a match, the app analyzes the risk of exposure based on the method and parameters established by the public health authority. If the risk exceeds a predetermined threshold, the app displays an exposure notification to the app user. The notification can include guidance and instructions. Figure 3 provides an overview of this process.

In August 2020, Microsoft partnered with APHL to establish a key server that could be used by all U.S. states—the National Key Server. With its launch, apps from different U.S. states could be interoperable, so that app users can find out if they have been exposed without needing to download and use apps from multiple states.[38] This feature is particularly important in regions where commuters regularly cross jurisdictional boundaries (e.g., in neighboring areas of Washington D.C., Maryland, and Virginia). Further, according to APHL, the server also reduces the burden of each state's public health agency needing to build and host its own key server.

In addition to the National Key Server, APHL manages a central verification server, referred to as the Multi-tenant Verification Server, which was launched in September 2020. APHL made the verification server available to reduce the effort needed by public health agencies to bring an exposure

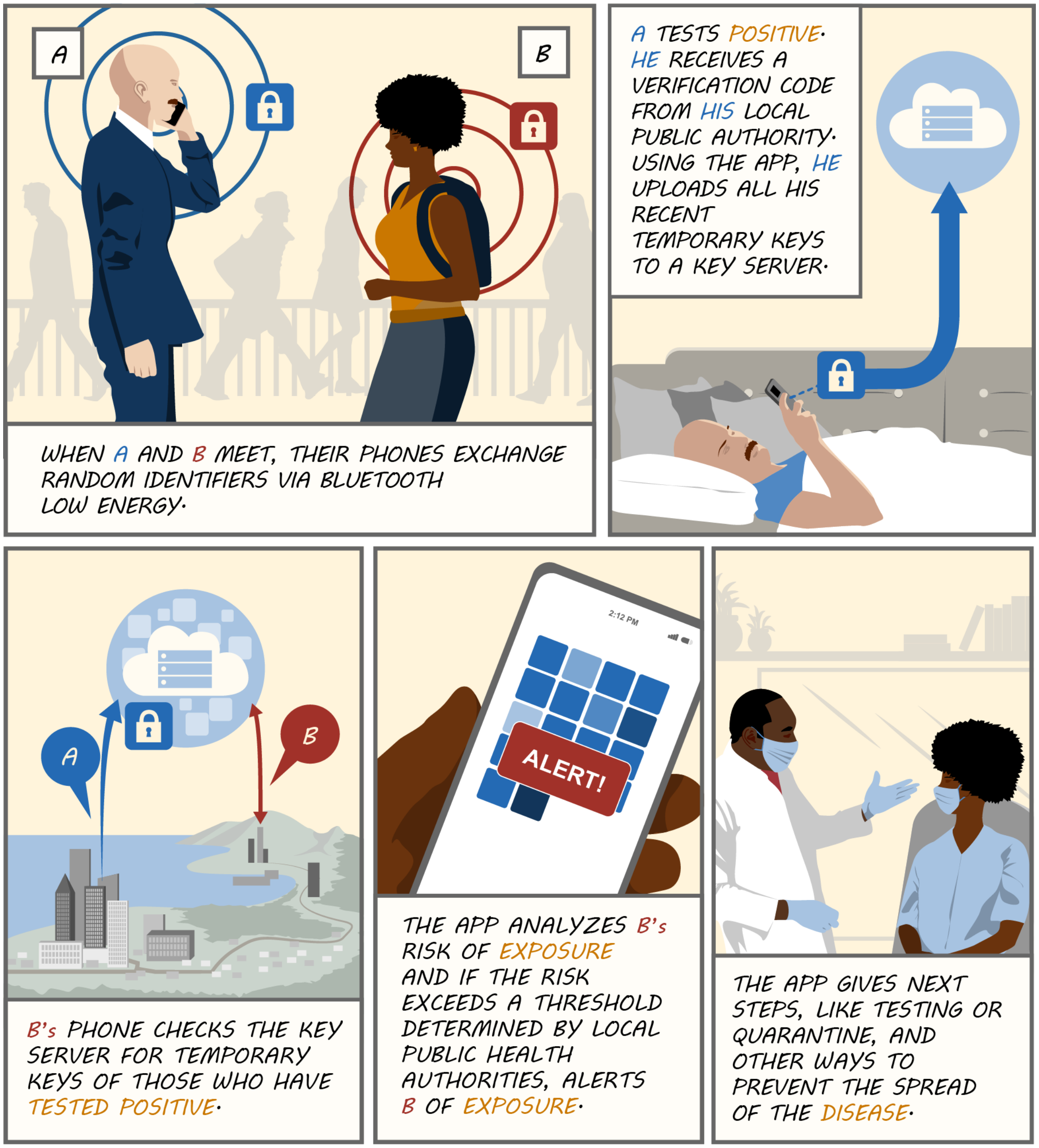
[37]The Express option works differently on iPhones and Android phones. For iPhones, the Express option is built into the operating system and can be activated by users in the iPhone settings. To receive exposure notifications, no app is required and therefore it is said to have "app-less" functionality. For Android smartphones, states develop the configuration settings (e.g., risk parameters), and Google then develops the app, which states can then use. For Apple devices, the Google Apple system works on iPhones running at least iOS 12.5. For Android, the system works for any smartphone capable of running Android version 6.

[38]App interoperability means that a person using an app from one state could receive an exposure notification based on an encounter with any other person who had an app that also used this server, such as a person from another state.

notification app to their jurisdiction. As a part of the Google Apple system, APHL noted that a verification server is necessary to ensure a user has received a positive test result before uploading their temporary keys to the National Key Server. APHL also noted that rather than each public health agency standing up its own verification server and deciding on a verification approach, providing one verification server reduces the time and cost to deploy the Google Apple system. For the states and territories with apps, nearly all were using the National Key Server, while over two-thirds were using the Multi-tenant Verification Server as of August 2021, according to APHL.[39]

[39]Although a verification server is necessary, it does not have to be the Multi-tenant Verification Server, so some states elected to use their own verification servers.

Figure 3: Overview of the exposure notification process used by state apps



Source: GAO analysis. | GAO-21-104622

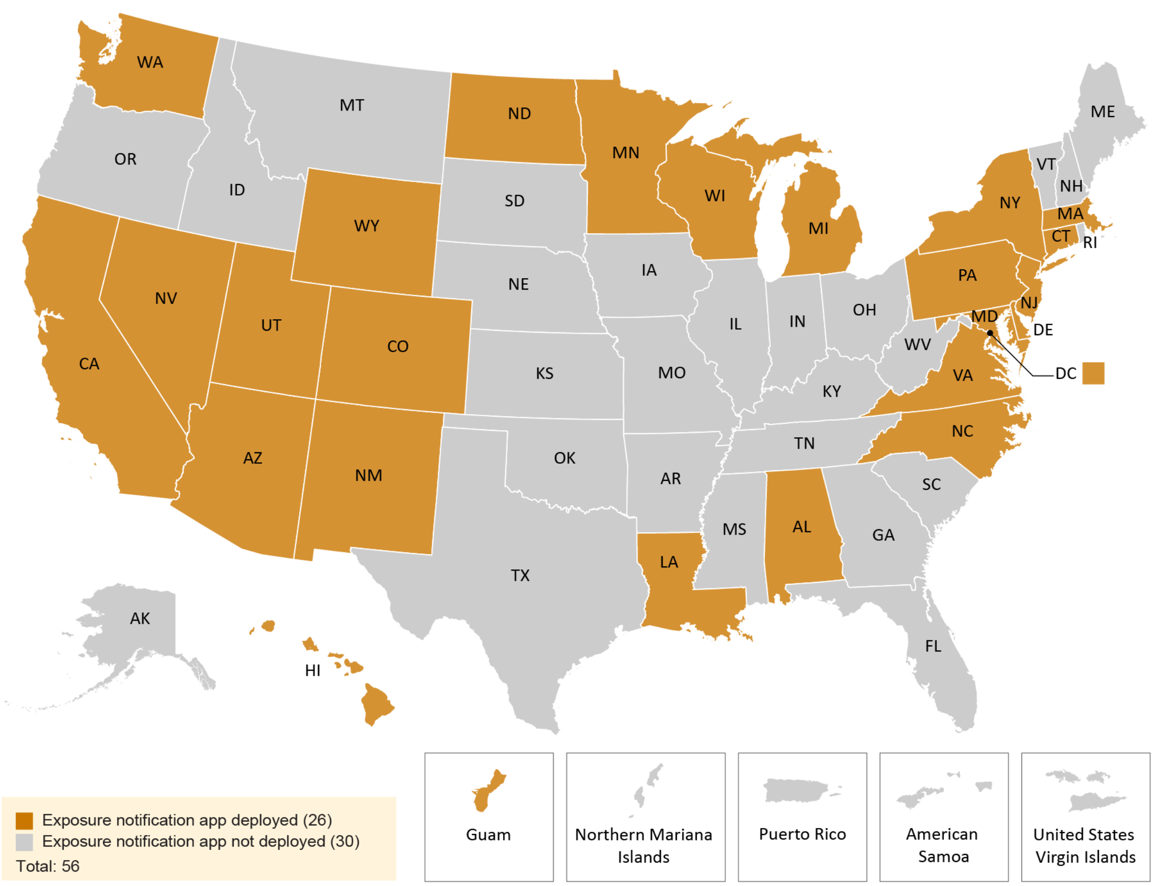
3 Deployment and Adoption of Exposure Notification Apps

Almost half of U.S. states have deployed an exposure notification app. In the absence of a national exposure notification app, states have independently launched their own apps at different times, resulting in a staggered rollout. States have developed and deployed apps using the Google Apple system and about half have customized their apps, which provides the apps with more flexibility and functionality. According to officials from selected states, development time, costs, and levels of adoption have varied.

3.1 About half of the states have deployed an exposure notification app

As of June 2021, 26 of 56 U.S. states (including territories and the District of Columbia) have deployed an app (see fig. 4). Unlike other countries, the U.S. does not have a national exposure notification app; instead, states have independently deployed individual apps.

Figure 4: Map of deployment of exposure notification apps by U.S. states and territories, as of June 2021

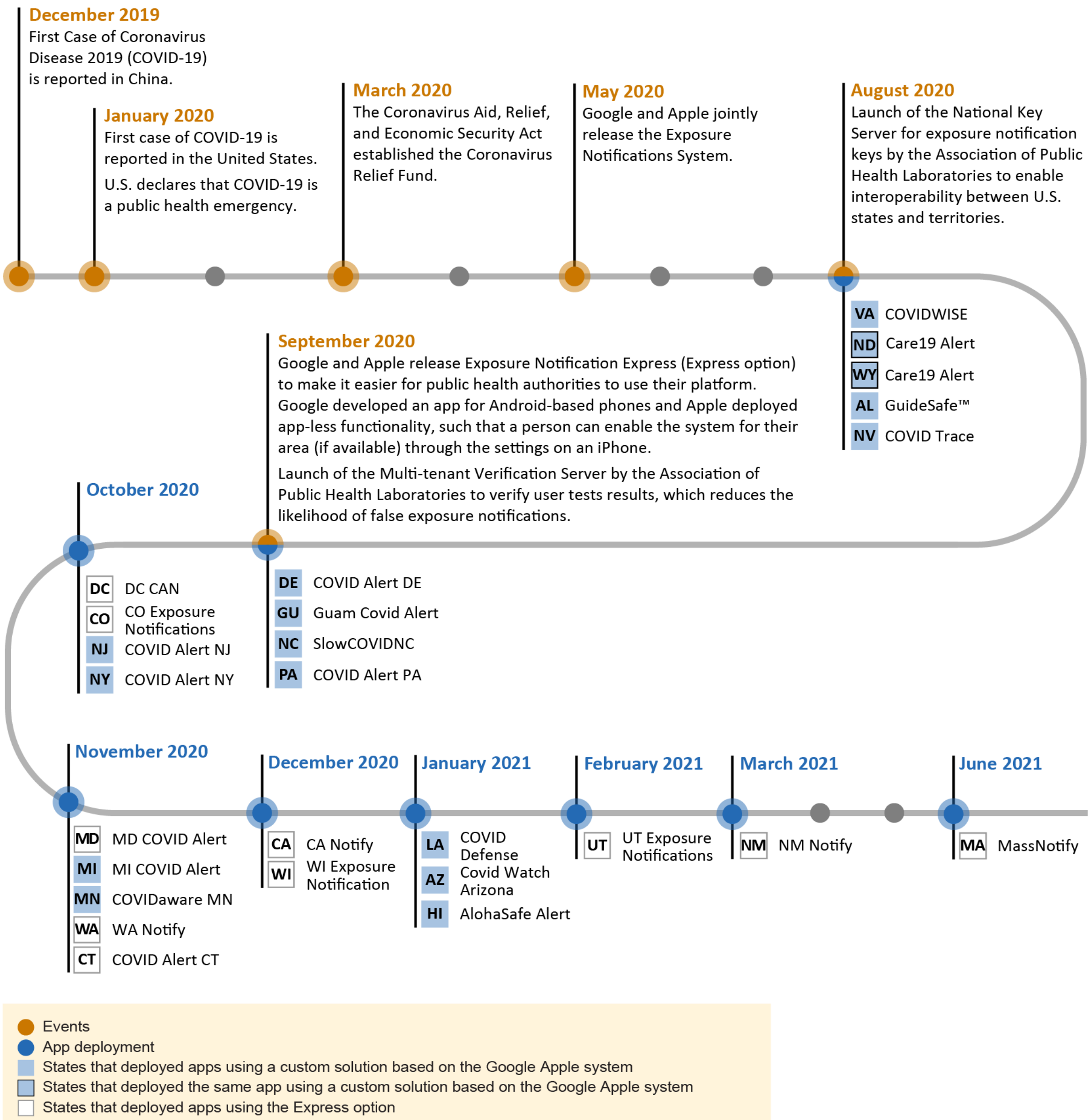


Source: GAO analysis of data from Goggle, Apple, the Association of Public Health Laboratories, and other sources, including state-level public health departments' websites. | GAO-21-104622

The patchwork of app deployment shown in figure 4 arises from the fact that public health authorities at the state and territorial levels decide whether and when to deploy an app. Furthermore, there was no existing option for a national app that states could use, according to CDC documentation. As of June 2021, 26 out of 56 states had deployed apps. Officials from seven selected states that had not deployed an app cited several reasons for that decision, including limited cell phone coverage in rural areas or other challenges related to the deployment and use of an app (see ch. 4 for additional detail). They also cited competing priorities, such as natural disaster response or vaccine distribution efforts, and were concerned that exposure notification app development would divert limited resources away from other priorities.

The 26 states deployed apps over a span of 10 months, in a staggered rollout beginning in August 2020. Figure 5 provides a timeline of app deployment and related events. Virginia was the first state to deploy an exposure notification app, in August 2020, and Massachusetts was the most recent, in June 2021. Seventeen of the states deployed an app between October 2020 and June 2021, which was after the Express option was made available (see fig. 5).

Figure 5: Timeline: Deployment of Google Apple custom exposure notification apps or the express option by U.S. states and territories and related events, as of June 2021



Source: GAO analysis of data from Google, Apple, the Association of Public Health Laboratories, and other sources. | GAO-21-104622

Note: The timeline indicates the Google Apple exposure notification option that was initially deployed by the state (i.e., custom or Express). Seven states deployed the Express option after initially deploying a custom app (Minnesota, Nevada, Hawaii, New York, Virginia, Louisiana, and New Jersey) between January and April 2021. In addition to exposure notification apps based on the Google Apple system, a few states developed smartphone apps to help people monitor their COVID-19 symptoms or assist in recalling the places they had visited when providing that information to a contact tracer. For example, in April 2020, Utah deployed an app which allowed residents to check their symptoms, and privately share a subset of their location information with public health officials to aid in the contact tracing process. In summer 2020, Utah disabled the location-based services in this app.

3.2 About half of the states use a customized app

Of the 26 U.S. states that had deployed apps as of June 2021, all are using a version of the Google Apple system.[40] With this system, public health authorities can choose to develop customized apps, use the Express option, or use both in tandem (see table 2). States could use, for example, a customized app for Android and the Express option for iOS smartphones.[41]

[40]In addition to the U.S., most countries with an app use BLE (primarily using the Google Apple system); approximately one-third use GPS. Some countries use both BLE and QR codes; for example, the United Kingdom's National Health Service's app uses both the Google Apple system and QR codes to check-in to locations.

[41]One of the selected states uses a customized app for both Android and iOS and also enabled the Express option for iOS.

Table 2: U.S. states deployment of apps using the Google Apple Exposure Notifications system

States	Customized app	Express option
Alabama	●	○
Arizona	●	○
California	○	●
Colorado	○	●
Connecticut	○	●
Delaware	●	○
District of Columbia	○	●
Guam	●	○
Hawaii	●	●
Louisiana	●	●
Maryland	○	●
Massachusetts	○	●
Michigan	●	○
Minnesota	●	●
Nevada	●	●
New Jersey	●	●
New Mexico	○	●
New York	●	●
North Carolina	●	○
North Dakota	●	○
Pennsylvania	●	○
Utah	○	●
Virginia	●	●
Washington	○	●
Wisconsin	○	●
Wyoming	●	○
Total	**16**	**17**

Legend: ● = State or territory that is using a version of the Google and Apple Exposure Notifications system; ○ = State or territory that is not using the identified version of the Google Apple system.

Source: GAO compilation of data from selected states, related documents, interviews, and other sources. I GAO-21-104622

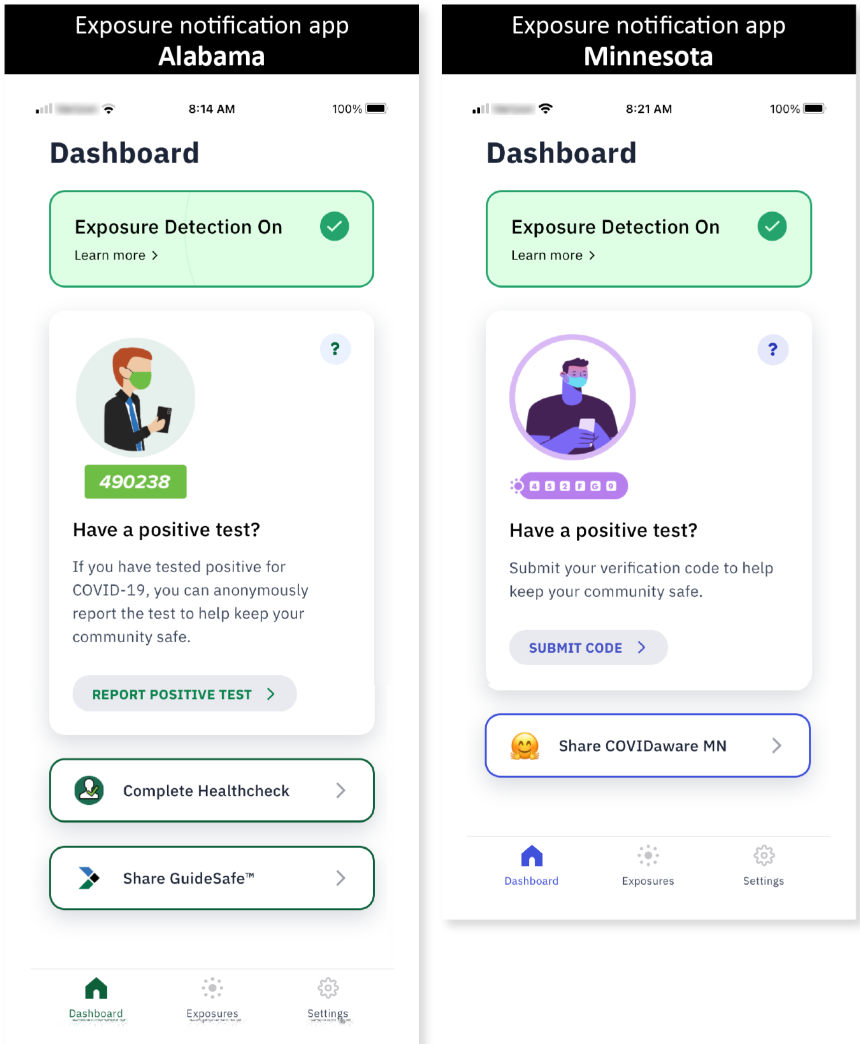
Note: State public health authorities can deploy customized exposure notification apps, which may offer unique functions and features. State public health authorities can also elect to use the Express option of the Google Apple system. The Express option provides convenience and efficiency but potentially less flexibility to tailor exposure notification functionality. The total in the table (33) does not equal the number of states with apps (26) because some states use both a customized app and the Express option.

To build a customized exposure notification app, public health authorities can seek external technical support (e.g., third-party developers, nonprofit organizations, or university partners). For the Express option, public health authorities can provide Google and Apple an electronic configuration file that includes instructions and content, including the risk parameters for enabling an exposure notification and messaging for app users. While states can use their own internal technical team or seek outside help to develop their app, officials from all nine of the selected states we interviewed said they had limited technical expertise and resources and received varying levels of external support to deploy their apps, regardless of whether they used customized apps or the Express option.

According to Google and Apple representatives, the Express option was developed to help states quickly and easily deploy their app. However, the Express option does not offer states the same flexibility to tailor the functions and features of their app as do customized exposure notification apps.

For example, a customized app may help users identify testing facilities and access state-level statistics about COVID-19 infections and death rates. State officials noted that they included these features to provide information to the public outside of their agencies' websites, which they hoped would encourage people to download and use their app. Based on our observations of exposure notification apps for the selected states, a common customized function was the ability to share the app with others. Figure 6 shows screenshots for two customized apps. These images illustrate how an app can be tailored to offer unique functions in the user interface. For example, one screenshot illustrates a unique function, "Healthcheck," which allows app users to report any COVID-19 related symptoms, exposure history, and testing history to their public health authority.

Figure 6: Screenshots of two customized exposure notification apps



Source: GAO review of selected exposure notification apps GuideSafe™ (iOS), Alabama Department of Public Health – University of Alabama at Birmingham and COVIDaware MN (iOS), Minnesota Department of Health, Minnesota IT Services. | GAO-21-104622

Note: The number in the image on the left (490238) is an illustration of a verification code that would be provided by a public health authority to an app user to verify the positive results of a COVID-19 test. A user can then voluntarily input this code in the app to submit their recent temporary keys.

Based on our review of the apps for the nine selected states, among other qualitative differences between state apps, we noted variation in the depth and scope of guidance information provided to app users. Specifically, some states provided more detailed information on symptoms, testing, and quarantine. We also found that the apps' privacy use agreements provided varying details on how the apps protect privacy, including how users can delete their data.[42]

3.3 States reported that app development time and cost varied based on several factors

Officials from each of the nine selected states we interviewed and the two additional states that provided written information varied in their reported app development time frames and costs.[43] Some public health authorities from these states attributed these variations to several factors, including legal review and marketing efforts. Officials from nine of the 11 states reported that the time to develop their apps ranged from less than 2 months to over 5 months. This time included the development of the apps, as well as conducting legal reviews of contracts, preparing marketing campaigns, and choosing to pilot the app prior to the full release. States that chose the Express option generally noted shorter development times.

The cost of app development also varied according to the information reported to us by officials from the 11 states.[44] One state reported zero development costs because a nonprofit organization developed the state's app, while another state reported development costs of $700,000.[45] State officials noted that their marketing costs also varied; costs ranged from $380,000 to $3.2 million, as of June 2021.

States used federal funding for development and marketing costs; some used state funding as well. Six of the nine states reported that they used CARES Act funding to support the development of their apps or marketing costs. However, according to the CDC, which distributes certain CARES Act and supplemental COVID-19 relief funds through its Epidemiology and Laboratory Capacity for Prevention and Control of Emerging Infectious Diseases cooperative agreement,[46] exposure notification apps are allowable expenses through these awards, but the agency does

[42]Some of the exposure notification apps had embedded links to the public health authorities' websites, which provided access to the state's privacy use agreement or other information.

[43]We interviewed state public health officials from a non-generalizable sample of nine states that had deployed an exposure notification app as of January 1, 2020: Alabama, Colorado, Connecticut, Minnesota, Nevada, North Carolina, Pennsylvania, Virginia, and Washington. We also reached out to two other states, Louisiana and Utah, which deployed apps in the later stages of our evidence collection about the status of their efforts to deploy an app and received written feedback to our structured questions.

[44]This includes the nine selected states we interviewed and the other two states that provided written responses to our questions.

[45]We did not independently verify the states' reported costs.

[46]As part of the Coronavirus Aid, Relief, and Economic Security Act (CARES), Coronavirus Preparedness and Response Supplemental Act, and Paycheck Protection Program and Health Care Enhancement Act supplements, the cooperative agreement awarded approximately $11 billion to support the domestic response to COVID-19. See CARES Act, Pub. L. No. 116-136, 134 Stat. 281 (2020); Coronavirus Preparedness and Response Supplemental Appropriations Act, 2020, Pub. L. No. 116-123, 134 Stat. 146 (2020); Paycheck Protection Program and Health Care Enhancement Act, Pub. L. No. 116-139, 134 Stat. 620 (2020). An additional award of $19.11 billion from the Coronavirus Response and Relief Supplemental Appropriations Act of 2021, Pub. L. No. 116-260, Div. M was awarded to continue to shore up domestic response efforts to COVID-19. See Consolidated Appropriations Act, 2021, Div. M, Pub. L. No. 116-260, 134 Stat. 1182 (2020).

not require recipients to report on use of funds to support exposure notification apps.

3.4 Officials reported varying download levels and use

Different app download levels (or activations for states using the Express option) were reported by officials from the nine selected states we interviewed and the two additional states that provided written information.[47] Specifically, four states reported less than 1 million, four states reported 1 to 2 million, and two states reported more than 2 million downloads (or activations), as of June 2021.[48] The other state does not track these data. According to Google and Apple representatives, states that initially deployed a custom app and then later added the Express option, experienced a significant increase in activations. Specifically, representatives stated that the adoption rate quadrupled for four states that added the Express option (Nevada, New Jersey, New York, and Virginia). However, there may be other factors that affect adoption rates. Further, the number of downloads and activations is not an accurate reflection of the number of people using the app. For example, a person could download or activate the app and not use it, or could download the app multiple times. See section 4.5 for additional information on this issue and appendix II for additional information on state app adoption rates.

In addition, different levels of app use were reported by officials from the nine selected states we interviewed and the two additional states that provided written information. Specifically, for two states the number of times their app users received exposure notifications as of June 2021 were above 30,000 (31,000 for one state and 42,000 for the other), while four states reported notifications that ranged from about 900 to 3,800; the remaining five states did not track these data. However, the number of notifications depends on a variety of factors, including the extent of the app users' contacts.

Further, limited data are available on the extent to which exposure notifications affected people's behavior, according to public health officials and studies we reviewed. For example, public health authorities do not know whether app users are actually using the app and following instructions for next steps contained in the alerts. Seven of the nine selected states that we interviewed said that they did not track whether app users actually sought testing or medical care based on the receipt of an exposure notification from an app; one state said it was done inconsistently and the other remaining state did not respond to our request for these data.

[47] Download data includes Android and iOS phones in states with customized apps; downloads for Android phones in states using the Express option; or "activations" for iOS phones in states using the Express ("app-less") option.

[48] States with customized apps can calculate download levels for Android and iOS smartphones from data obtained from Google and Apple apps stores. However, for states using the Express option, they can determine downloads for Android devices but must estimate the number of users that activated the app on iOS smartphone.

4 Challenges Associated with Exposure Notification Apps

We identified the following five categories of challenges associated with these apps:

- Accuracy of measurements
- Privacy and security concerns
- Adoption and use of apps
- Verification code delays
- Evidence of effectiveness

4.1 Accuracy of measurements

The techniques that exposure notification apps use to measure distance have technical limitations that can result in users receiving false exposure notifications. For example, BLE wireless radio technology, used to measure the distance between two smartphones, cannot always reliably measure whether two smartphones are within 6 feet of each other. In addition, research has demonstrated that the BLE signal strength does not always decrease with distance, and can even increase with distance under certain conditions.[49] For example, objects in the environment between a sender and a receiver (e.g., furniture, walls, people) can impact the signal, causing the received signal strength to vary substantially. Other factors include the type of phone and antenna, whether the phone is being held or is in a pocket or otherwise obstructed location, and the position of one phone with respect to the other phone (e.g., if it has a 90 degree rotation or is facing down).

As a result, a person could receive a notification even if that person was far away or separated by a physical barrier from an infected person. Such a result, known as a false positive, can lead a person who has been notified to take unnecessary steps, such as getting tested, or self-quarantining. Further, false positives could reduce that person's confidence in the app, which could lead to them not using the app or using it less often. In addition, without accurate measurements, an app could fail to detect that two people are in close proximity for a certain amount of time, leaving the potentially exposed person with a false sense of security—a false negative.

To help address these limitations, various industry experts have highlighted the potential of using other technologies to perform measurements instead of or in addition to BLE, including ultra-wideband signals and ultrasound.[50] Several studies have found that these other technologies may be more accurate than BLE.[51] In

[49]See Douglas Leith & Stephen Farrell, "Coronavirus Contact Tracing: Evaluating the Potential of Using Bluetooth Received Signal Strength for Proximity Detection," *ACM SIGCOMM Computer Communication Review*, vol. 50, no.4 (2020); 1-11.

[50]Like BLE, ultra-wideband is a wireless radio transmission technology, but it could provide measurements that are more accurate. However, ultra-wideband is only available on certain newer smartphones. Ultrasound refers to the transmission of inaudible acoustic pulses in the ultrasonic frequency range between phones.

[51]See, for example, N. Ahmed et al., "A Survey of COVID-19 Contact Tracing Apps," *IEEE Access*, vol. 8 (July 2020): 134577-134601, accessed December 1, 2020, https://doi.org/10.1109/ACCESS.2020.3010226; and J. Meklenburg et al., "SonicPACT: An Ultrasonic Ranging Method for the Private Automated Contact Tracing (PACT) Protocol," *arXiv.org* (Dec. 2020): 1-14, accessed November 24, 2020, https://arxiv.org/abs/2012.04770.

addition, researchers have suggested that exposure notification apps could use sensor technologies to improve distance estimation based on BLE measurements, such as by using a gyroscope, an accelerometer, or a magnetometer.[52] For example, these technologies could help to detect the position of the phone. However, thus far, there has been only limited use of these technologies. Specifically, while some entities with an exposure notification app use ultrasound technology for distance estimation, including several U.S. universities, as of June 2021, we did not find any exposure notification apps that use ultra-wideband signals, a gyroscope, accelerometer, or a magnetometer.

4.2 Privacy and security concerns

Privacy

Officials from all nine of the selected states identified privacy as an important factor in determining whether to implement an exposure notification app and in selecting the system used by the app (i.e., Google Apple system). In particular, officials stated that users would likely not adopt an app that collected their personal information, including location data.

Despite the privacy protections built into the apps by Google and Apple, the public may lack confidence that their privacy is protected, in part, due to a lack of independent assessments and federal legal protections for the privacy of app data. In particular, CDC's guidance on the implementation and use of exposure notification apps recommends that the apps go through independent security and privacy assessments,[53] and that the results be made publicly available.[54] However, we found that none of the nine selected states had fully implemented this guidance. Specifically, officials from five of the nine selected states reported that security and privacy assessments were performed; however, the results were not made publicly available. The remaining four states reported that these assessments were not performed.

Currently there is no federal law that provides the public with clearly applicable privacy protections for the information that exposure notification apps gather. Specifically, in January 2019, we reported that the U.S. did not have a comprehensive internet privacy law governing the collection, use, and sale or other disclosure of consumers' personal information. Accordingly, we recommended that Congress consider developing legislation on

[52]A gyroscope is a device used for measuring or maintaining orientation and angular velocity. An accelerometer is a device used to measure acceleration forces. A magnetometer is a device that measures the strength and sometimes the direction of magnetic fields.

[53]An example of such an assessment is a privacy impact assessment that is used by federal agencies in response to requirements in the E-Government Act of 2002. Among other things, the assessment is an analysis of how personally identifiable information is handled to ensure compliance with applicable privacy requirements and manage privacy risks. Also, a privacy impact assessment includes a formal document detailing the process and the outcome of the analysis. See Office of Management and Budget, *Managing Information as a Strategic Resource*, Circular A-130 (Washington, D.C.: July 2016).

[54]Centers for Disease Control and Prevention, *Guidelines for the Implementation and Use of Digital Tools to Augment Traditional Contact Tracing*, version 1.0 (Atlanta, Ga.: Dec. 15, 2020) and *Preliminary Criteria for the Evaluation of Digital Contact Tracing Tools for COVID-19*, version 1.2 (Atlanta, Ga.: May 17, 2020).

internet privacy that, among other things, would enhance consumer protections.[55] Legislation governing the collection and use of consumers' personal information—in particular for exposure notification apps—could help to safeguard their privacy, and provide the public with greater assurance that its privacy is protected. However, such legislation has not been enacted.[56]

In the absence of such legislation, individual companies have set their own privacy requirements for exposure notification apps, including requirements on the collection and use of the data. For example, Google and Apple have each established requirements for their exposure notification system and their respective app stores regarding data collection and privacy. These requirements specify that only the minimum amount of user data that is necessary for response efforts should be collected, and that the data may only be used for such efforts.[57] In addition, the requirements state that the apps cannot collect any information to identify or track the precise location of users.

Security

To ensure that exposure notification apps function as intended and that user privacy is protected, it is important that developers build in security protections. However, security assessments of these apps are limited.

Security considerations should include the supporting infrastructure—such as central servers—and address how the data are stored and maintained, including appropriate authentication and access controls. Security incidents could lead to privacy violations (e.g., identifying or tracking users) or disrupt the functioning of the app (e.g., inserting false data). This would likely result in the public's loss of confidence in the apps, potentially leading to decreased use. Researchers have identified a variety of potential threats for

[55]GAO, *Internet Privacy: Additional Federal Authority Could Enhance Consumer Protection and Provide Flexibility*, GAO-19-52 (Washington, D.C.: Jan. 15, 2019). Other federal laws governing health information, including the *Health Insurance Portability and Accountability Act*, may not provide consistent, clearly-applicable privacy protections for the information that likely would be gathered and used in digital contact tracing activities. See Congressional Research Service, *COVID-19: Digital Contact Tracing and Privacy Law*, LSB10511 (Washington, D.C.: July 9, 2020).

[56]Congress has introduced several bills over its last two sessions that address aspects of exposure notification apps or digital contact tracing tools. Of the bills that have been introduced, one that was enacted into law related to implementing a national strategy for contact tracing and enhancing information technology and data modernization capabilities (*American Rescue Plan Act of 2021*, Pub. L. No. 117-2, § 2401, 135 Stat. 4, 40 (2021)). However, it does not specifically address exposure notification apps or the associated privacy issues. In addition, at least one state passed a law regarding the use of location data for contact tracing. Specifically, in June 2020 Kansas passed a law stating that contact tracing shall not be conducted through the use of any service or means that uses cell phone location data to identify or track, directly or indirectly, the movement of persons. See K.S.A. § 48-961 (2021).

[57]See, for example, Google, *Google COVID-19 Exposure Notifications Service Additional Terms*, (last modified May 4, 2020), accessed May 16, 2021, https://blog.google/documents/72/Exposure_Notifications_Service_Additional_Terms.pdf; and Apple, *Exposure Notification APIs Addendum*, (last revised May 4, 2020), accessed May 16, 2021, https://developer.apple.com/contact/request/download/Exposure_Notification_Addendum.pdf.

exposure notification apps.[58] Table 3 identifies several examples of these threats and their potential effects.

Table 3: Examples of threats and their effects for exposure notification apps

Threat	Description	Potential Effect
Re-identification	Comparing exposure notifications with personal logs of a phone owner's recent contacts.	The identity of an infected app user is revealed.
Denial of service	Broadcasting fake encounter messages to consume resources of other smartphones.	Loss of availability of a smartphone due to the additional battery power, storage, and processing time required to store and process the fake messages.
Phone tracking	Tracking a user's location by analyzing the information sent in encounter messages, such as the random identifiers.	A user's location and movements is revealed.
Relay (or replay)	Re-transmitting captured encounter messages at the same or a different location.	Smartphone receives exposure notification despite not coming in close contact with an infected person (i.e., false positive).

Source: GAO review of selected literature. | GAO-21-104622

The Google Apple system includes features intended to mitigate these threats. In addition, according to representatives from these companies, they had a third party perform a security assessment of the system. There are also ongoing assessments on the security of exposure notification apps, including on the Google Apple system.[59] However, as exposure notification apps are a relatively new technology, these assessments have, as of now, limited data and results. Further, as previously stated, the selected states have not provided the results of independent security assessments in a public format, as recommended by CDC guidance.[60]

[58]See, for example, N. Ahmed et al., "A Survey of COVID-19 Contact Tracing Apps"; Massachusetts Institute of Technology Lincoln Laboratory, "Exposure Notification Security Assessment Considerations," Lexington, Massachusetts. Unpublished Article; and M. Chowdhury et al., "COVID-19 Contact Tracing: Challenges and Future Directions," *IEEE Access*, vol. 8 (Nov. 2020): 225703-225729, accessed February 16, 2021, https://ieeexplore.ieee.org/document/9252092.

[59]For example, the Massachusetts Institute of Technology's Lincoln Laboratory has developed security assessment considerations for the Google Apple system and conducted a security assessment of one of the apps used in the states. In addition, in February 2021, DHS's Science and Technology Directorate's Silicon Valley Innovation Program awarded funding to a company (AppCensus) for a project to develop testing and validation services. In April 2021, the company reported that it had identified a vulnerability with apps using the Google Apple system. Specifically, the company reported that preinstalled apps could gain access to system logs made by exposure notification apps on Android devices. According to the company, these logs could include information, such as whether a person had received an exposure notification and the random identifiers that a smartphone device had sent and received. Google representatives stated that a fix for this vulnerability was available as of May 5, 2021, and that there is no evidence that it was exploited.

[60]Centers for Disease Control and Prevention, *Guidelines for the Implementation and Use of Digital Tools to Augment Traditional Contact Tracing*, version 1.0 (Atlanta, Ga.: Dec. 15, 2020).

4.3 Adoption and use of apps

States have also faced challenges attracting public interest in downloading (or activating) and using an exposure app. State public health officials told us that, in spite of their marketing and outreach efforts, getting people to download (or activate) and use their app is difficult for the following reasons.

Lack of trust. Mistrust of governmental health authorities and technology companies can lead people to forgo using apps, according to literature and state officials. For example, officials from six of the 11 states cited public concerns about the use of apps for government surveillance (e.g., using the apps to track users' location) as a leading obstacle to app adoption,[61] even though these apps do not collect location data. In addition, the public may not trust big technology companies with their data. These concerns may be exacerbated by reported vulnerabilities with apps using the Google Apple system. Specifically, as previously stated, a company reported that other apps on a phone could potentially gain access to sensitive information, including whether a person had received an exposure notification. In addition, the lack of trust regarding the use of apps may be intensified by other incidents where technology companies potentially misused consumers' personal information. For instance, in April 2018, Facebook disclosed that a Cambridge University researcher may have improperly shared the personal data of 87 million of its users, which followed other incidents of misuse of personal information.[62] Also, multiple officials noted that the public was skeptical of the Google Apple system, since it is a joint initiative between U.S. technology companies and the government that involves personal health information. In particular, officials from three states indicated that the public expressed concerns about the perceived "big brother" nature of exposure notification.

Lack of understanding of how apps function. Multiple officials said they frequently had to counter misinformation about how the apps work and the data they collect. For instance, officials from one state reported that they emphasized the app's use as a public health communication tool because of misinformation describing the exposure notification app as a data collection tool used to surveil and track the public.

Also, multiple officials said the public had a limited understanding about the apps' privacy-preserving features. Officials from three states said that they believed the public did not understand the technical aspects of the apps, which may include how the random identifiers do not reveal personal information.[63] Such misunderstandings may contribute to public unwillingness to download or use the apps. Further, such misunderstandings may also contribute to hesitance to enter verification codes for people who had downloaded an app on their device. Specifically, sometimes people receive positive COVID-19 test

[61] The 11 states include nine from our selected sample plus two additional states.

[62] GAO-19-52.

[63] According to Google and Apple documentation, the random identifiers exchanged with other smartphones are not linked to the app user's identity or phone number and change on a periodic basis (e.g., every 10 minutes).

results long after the app has been downloaded. Because people may not have initially understood (or have forgotten) how the app works, including the apps' built-in privacy preserving features, some app users many not want to input their verification codes to prompt exposure notifications to other people, according to officials from selected states.

Lack of awareness of the availability of the apps. Officials from several states noted that it was difficult to make people aware of the apps. For example, officials from multiple states noted that they thought building awareness in closely connected communities with influential leaders would encourage people to download and use an app. However, one state tried, but was unsuccessful, in recruiting support from some of these groups, including churches and a college football program. One official said the lack of support was a lost opportunity to build awareness and increase that state's app adoption rate. Further, some states reported having minimal resources for marketing, which one official said resulted in low awareness of the state's app. Three states reported that a federally led national marketing campaign would have helped promote their app and drive higher rates of adoption. Similarly, officials from a national health organization reported that a national public awareness campaign led by the CDC would help encourage adoption and be more cost-effective than individual state campaigns.

Limited access. Another reason it can be difficult to get people to download and use an exposure notifications app is lack of access to a smartphone, reliable cellular coverage, and broadband internet service, according to selected states and literature. Indeed, officials in a few states told us one reason they chose not to deploy an app was the lack of necessary supporting infrastructure or internet service in rural areas. To be effective, exposure notification apps need to be downloaded and used by a critical mass of the general public. While the levels of adoption needed to achieve certain measures of effectiveness are not well established (see section 4.5), increasing the number of people using the app should result in a greater likelihood that users who come in close contact with an infectious person will be notified of potential exposure, according to CDC and the Massachusetts Institute of Technology's Lincoln Laboratory.

4.4 Verification code delays

States were challenged in distributing verification codes quickly to the public. As previously stated, these codes are used to confirm that a person had a positive test or diagnosis before they are able to upload their recent temporary keys to the National Key Server. For people to be notified of potential exposure quickly, these verification codes need to be distributed in a timely manner and users need to voluntarily decide to use them to notify recent contacts.

Officials from several of the selected states reported that their initial process for distributing the codes required a public health official, such as a contact tracer, to provide a person with the verification code via phone after the person had received a positive test result or a confirmed diagnosis. However, states reported that, due to staffing shortages, in particular as cases surged, it sometimes took several days to provide the code. As a result, some app users who had tested positive for COVID-19 were delayed in submitting their verification codes to notify others of possible exposure, according to officials from selected states.[64] In addition, there can be delays in test results being available and provided to health care providers who report the results to local or state health officials. In particular, earlier in the pandemic, testing availability and turnaround time for results could take a week or more. Following the receipt of test results, the health care provider or laboratory then reports the results to local or state health officials. Any delays in this process could also contribute to delays in public health authorities' distribution of verification codes to individuals after the individual has received the confirmed diagnosis.

In addition, a few states noted that contact tracers did not always follow the state's processes for providing app users with a verification code to enter COVID-19 test results in the app. For example, when a contact tracer was conducting an interview with a person, they were supposed to ask if the person had downloaded the state's app, and if so, to provide them with a verification code. However, officials from one state stated that this was not always performed.

To help address this challenge, five of the nine selected states implemented an automated process to distribute the codes. Instead of providing the codes entirely through phone calls, some states also send text messages with the code or a link to a website with instructions for how to obtain the code. State officials reported that this automated distribution resulted in an increase in the number of verification codes disseminated to app users. For example, following implementation of the new process, one state's average distribution of verification codes increased from 15 to 85 a day, according to public health officials. In addition, officials from a different state reported that they had seen an increase in the number of codes redeemed, and improved the timeliness of code redemption following implementation of the new system. However, another state noted that, even after automating the process, it still took 4 days, on average, for a person to receive a verification code following a positive test result.

4.5 Limited evidence of effectiveness

We found limited evidence that exposure notification apps are effective at enhancing the speed or reach of manual contact tracing or at reducing the spread of disease. One reason for the dearth of evidence is that states collect limited data from exposure notification apps due to the emphasis on data privacy. In addition, little to no guidance exists on what data to collect and how to collect the data. As for slowing the spread of COVID-19, studies have not yet sufficiently demonstrated that exposure notification apps are having an effect. CDC and others have, therefore,

[64] If the user tests positive for COVID-19, a public health authority generates a verification code and then sends the user the code to verify the positive test results. A user can then voluntarily input this code in the app to submit recent temporary keys.

highlighted the need for additional research into the effectiveness of exposure notification apps in preventing the spread of disease.

4.5.1 States collect limited data from exposure notification apps

The privacy protections that are incorporated into the functionality of the existing apps limit the data available to public health authorities, which reduces the ability to measure and improve the effectiveness of the apps. For example, officials from all nine selected states said to preserve personal privacy, they do not collect data on who has installed an app, including who has received an exposure notification. In addition, states have limited data on how well the apps are working, including how changes to the formula used to calculate the level of risk affects the number of people provided with exposure notifications.[65] In addition, states do not collect location data, so they are unable to identify where disease spread is occurring.

Furthermore, states do not collect data on the speed of exposure notification, according to our review of information provided by selected states. Metrics on the speed of notification are not provided as part of the Google Apple system, though these data could be collected by the states individually, should they choose to, according to Google and Apple representatives. With fast-spreading diseases like COVID-19, the speed of contact tracing plays a critical role in reducing disease spread, allowing those who may have been exposed to take action more quickly. States could use the speed of notification as one indicator or metric of app effectiveness. According to Google and Apple representatives, the time between when a user submits their temporary keys to the key server and when a person would be notified is estimated to be between 4 and 10 hours. However, a few factors can delay the submission, including the amount of time it takes to receive a test result (e.g., time for test processing and reporting to the health care provider and to the local health officials) and when that person receives and uses the verification code.

4.5.2 States lack guidance on measuring effectiveness

States lack guidance for measuring the effectiveness of exposure notification apps. Officials from nearly all the selected states told us they wanted to gauge the impact of their apps and assess effectiveness, such as the enhanced reach through electronic notification. Officials from several of the selected states said that they had reached out to CDC for guidance regarding recommended approaches and indicators for measuring app effectiveness, which was confirmed by CDC officials. However, the requested information was not available. CDC officials indicated that they considered developing additional guidance to evaluate

[65] MITRE is planning to enhance the Exposure Notification Private Analytics portal with additional features, including the ability to analyze how changes in risk parameters affect the number of exposure notifications. The portal and the exposure notification analytics data it provides are only available to states using the Express option.

app effectiveness. However, they acknowledged there are limited app evaluation strategies available due to the lack of data from exposure notification apps and, as a result, they are not planning to develop additional guidance. Because of the lack of federal guidance, officials from states said they were "on their own" and began reaching out to other states and countries that had deployed apps for advice and best practices, such as metrics for measuring effectiveness. Officials from the majority of the selected states said they wished there had been additional guidance available, including how to measure app effectiveness; officials from three states used the analogy of "building the plane while flying it," to describe their experience deploying their apps with limited direction.

CDC has developed general guidance on exposure notification apps, such as minimum and preferred characteristics.[66] CDC also developed guidance to measure the success of manual contact tracing efforts, including both process and outcome metrics, but has not developed specific guidance on criteria to use in measuring app effectiveness, such as increased speed or reach compared to manual contact tracing.[67]

The lack of standardized metrics was identified as a challenge in President Biden's *National Strategy for the COVID-19 Response and Pandemic Preparedness* in January 2021. The strategy noted that states use and report different metrics for tracking COVID-19 response activities, including contact tracing, and called for common federal metrics to evaluate progress and the identification of areas where additional federal resources should be directed.[68]

In part due to the lack of federal guidance, selected states varied in the types of data that they are collecting to measure the overall effectiveness of their own apps and have developed their own metrics and indicators for determining how well the apps are working. States are using one or more of these metrics:

- App downloads or activations[69]
- Verification codes issued[70]
- Verification codes claimed[71]

[66]Centers for Disease Control and Prevention, *Preliminary Criteria for the Evaluation of Digital Contact Tracing Tools for COVID-19*, version 1.2 (Atlanta, Ga.: May 17, 2020); and *Guidelines for the Implementation and Use of Digital Tools to Augment Traditional Contact Tracing*, version 1.0 (Atlanta, Ga.: Dec. 15, 2020). CDC's May 2020 and December 2020 guidance and website information on digital contact tracing tools did not include a definition for effectiveness or any standardized metrics for states or indicators for measuring app effectiveness.

[67]Centers for Disease Control and Prevention, *Evaluating Case Investigation and Contact Tracing Success*, (Atlanta, Ga.: May 26, 2020), accessed June 9, 2021, https://www.cdc.gov/coronavirus/2019-ncov/php/contact-tracing/contact-tracing-plan/evaluating-success.html.

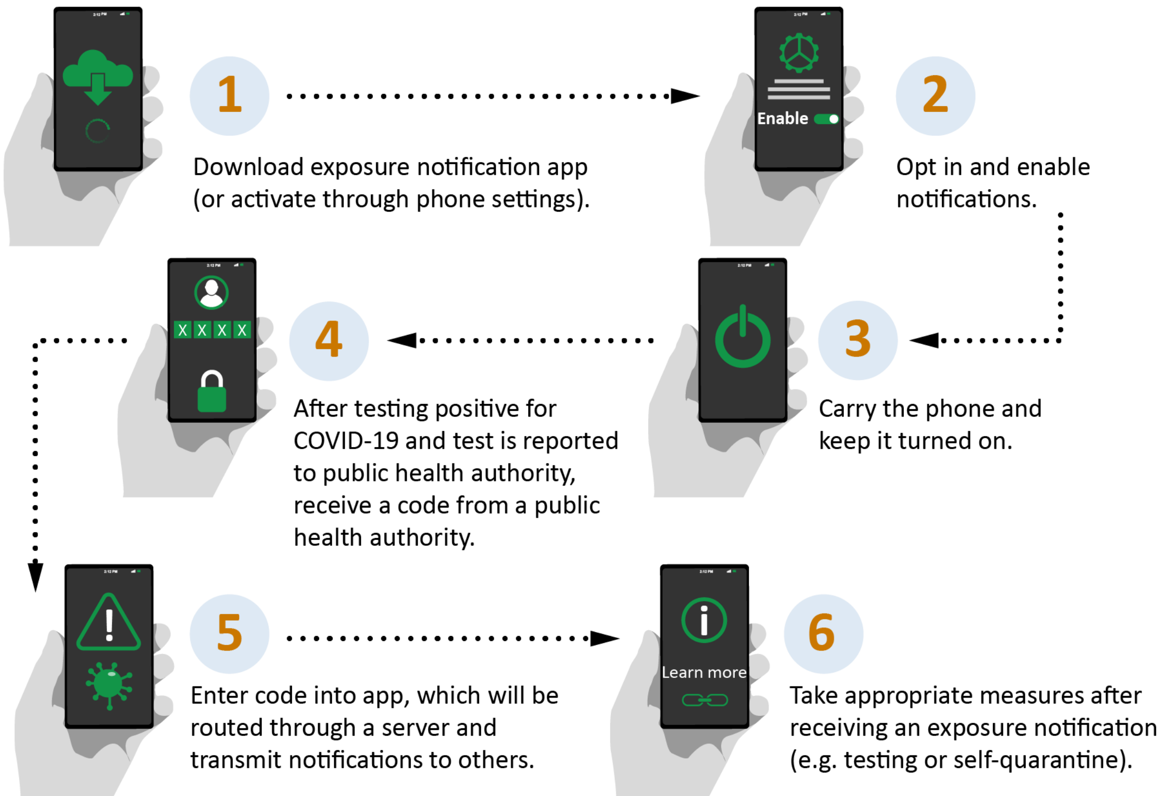
[68]The White House, *National Strategy for the COVID-19 Response and Pandemic Preparedness*, (Washington, D.C., Jan. 21, 2021).

[69]As previously mentioned, download data includes Android and iOS phones in states with customized apps; downloads for Android phones in states using the Express option; or "activations" for iOS phones in states using the Express ("app-less") option.

[70]Verification codes issued refers to the codes that are disseminated to app users with a positive COVID-19 test result. The codes may be provided on the phone by contact tracers or through other methods, such as text message.

[71]Verification codes claimed refers to the codes entered by app users with a positive COVID-19 test result that enables them to send the recent temporary keys to the National Key Server to notify others that they may be at risk.

Figure 7: Actions needed to achieve benefits of exposure notification apps



Source: GAO analysis of Google and Apple information. | GAO-21-104622

- Exposure notifications generated[72]

Yet, officials from eight of the nine selected states noted that some of these metrics provide a limited understanding of app effectiveness. Data on downloads, verification codes, and exposure notifications provide public health authorities some information to gauge how effective they are. However, these metrics do not indicate how quickly people were notified of exposure or timeliness relative to manual contact tracing alone. With regard to reach, the number of downloads gives an approximate, but not actual sense of the number of app users.

The number of downloads is not an accurate reflection of app usage. Officials from one state speculated that some people were downloading the apps out of curiosity but never enabling them on their smartphone. Further, after a person downloads the app, they need to perform a series of actions for it to be used as intended (see fig. 7). Therefore, a user

[72]Exposure notifications are alerts provided to close contacts of the app users who confirm a positive test or diagnosis using a verification code they enter into the app. However, they are only an estimate, as app users voluntarily provide this information.

could download but not use the app or download it more than once, according to public health officials from several selected states. Also, people could choose to not enable receiving exposure notifications; ignore notifications; and if they do test positive, not voluntarily provide that information. While download totals may represent the possible population of app users that could receive benefits (i.e., notification) from these apps, these limitations hinder states from understanding the effectiveness of using exposure notification apps.

Verification codes claimed by the people who have tested positive for COVID-19 and who entered the information in the app (which prompts exposure notifications to be sent to others) may also provide an indication of app use. Similarly, the number of exposure notifications gives a sense of how many people are notified of potential exposure to COVID-19, but it may provide limited insight into the effectiveness of the public health intervention because users need to voluntarily provide this information in their apps. Finally, none of the data indicate whether people changed behavior as a result of the notification.

While people seeking testing or medical care could be asked whether they sought testing or care due to an exposure notification from an app, such information may violate a user's expectations of privacy, according to officials from one state. Further, because states do not track who receives an exposure notification, states have a limited understanding of what impact, if any, these notifications have on disease spread and the overall effectiveness of their apps.

Nonetheless, public health officials from seven of the nine selected states said they believe the exposure notification apps have been effective and that their apps had been worthwhile. Officials from two states said they think adoption even at relatively low levels would help slow disease spread. Furthermore, exposure notification apps provided a new tool for states to use—at a time of urgent need—to limit the spread of COVID-19.

4.5.3 Evidence of reduced disease spread has been limited but additional studies are underway

We reviewed seven selected modeling studies that have sought to measure the effects of the use of apps on the spread of COVID-19. However, there are important limitations to these studies—such as limited evidence to support assumptions about behavioral changes—which hinder the ability to draw high-confidence conclusions about the apps effectiveness.[73] The studies we reviewed generally suggested that the use of exposure notification apps can reduce disease transmission.[74] In general,

[73]Infectious disease models are simplified versions of reality that help to characterize disease spread (see GAO-20-372 for an overview of infectious disease modeling). Other types of epidemiological studies of contact tracing apps that could be conducted in real world settings, rather than via modeling, face methodological, logistical, and ethical challenges, including the lack of empirical data, confounding factors that affect disease spread, and other issues.

[74]The selected studies we reviewed covered a range of geographic areas, including Washington State, the United Kingdom, Spain, and Switzerland, and were published between April 2020 and May 2021. Five of the seven papers are peer-reviewed publications. We identified the papers from our interviews with subject matter experts and a search of the literature. Studies we reviewed include:

the studies suggested that app usage can decrease COVID-19 infections and deaths, with the size of the estimated effects depending on the level of app adoption, among other things. For example, one peer-reviewed study estimated that, when 15 percent of the population used an exposure notification app, infections could be reduced by approximately 8 percent and deaths by about 6 percent. Another peer-reviewed study in the United Kingdom estimated that a 30 percent app uptake averted approximately one infection for every four infections that arose over a 4½-month period.

However, there are significant limitations to these modeling studies. For example, the models estimated outcomes by relying on assumptions about app usage and behavioral changes associated with notifications. These assumptions covered factors such as how many people used an app, how many app users had a positive test result, and how many app users self-isolated. In some cases, particularly with studies earlier in the pandemic, these assumptions were not grounded in research and were not otherwise well supported. For example:

- Assumptions in one study were that everyone notified of a potential exposure would self-isolate, with a 2 percent drop-out rate each day, and that 18 percent of infected people remained asymptomatic, with no variation in this rate across age groups.[75] These assumptions were not grounded in evidence because little to none was available at the time.
- A study of three counties in Washington State assumed in its simulations that it would take 2 days from symptom onset to receive a COVID-19 test result, which the authors characterized as a key assumption underlying the findings. However, in the earlier months of the

---

R. Hinch, et al., *Effective Configurations of a Digital Contact Tracing App: A Report to NHSX,* (April 16, 2020), accessed December 9, 2021, https://cdn.theconversation.com/static_files/files/1009/Report_-_Effective_App_Configurations.pdf?1587531217.

M. Abueg, et al., "Modeling the Effect of Exposure Notification and Non-pharmaceutical Interventions on COVID-19 Transmission in Washington State," *npj Digital Medicine*, (4, 49), (March 12, 2021) accessed March 12, 2021, https://www.nature.com/articles/s41746-021-00422-7.

C. Wymant, et al., "The Epidemiological Impact of the NHS COVID-19 App," *Nature*, Vol. 594, no. 7863 (2021).pp. 408-412, accessed February 25, 2021.

P. Rodríguez, et al., "A Population-Based Controlled Experiment Assessing the Epidemiological Impact of Digital Contact Tracing," *Nature Communications*, (January 26, 2021), accessed February 22, 2021, https://www.nature.com/articles/s41467-020-20817-6.

S. Marcel, et al., "Early Evidence of Effectiveness of Digital Contact Tracing for SARS-CoV-2 in Switzerland," *Swiss Medical Weekly*, (December 16, 2020), accessed March 9, 2021, https://smw.ch/article/doi/smw.2020.20457.

D. Menges, et al., "A Data-Driven Simulation of the Exposure Notification Cascade for Digital Contact Tracing of SARS-CoV-2 in Zurich, Switzerland," *JAMA Network Open*, (4 (4):e218184), (April 30, 2021), accessed July 13, 2021, https://jamanetwork.com/journals/jamanetworkopen/fullarticle/2779376.

Massachusetts Institute of Technology Lincoln Laboratory, "Simulated Automatic Exposure Notification (SimAEN): Exploring the Effects of Interventions on the Spread of COVID," Private Automated Contact Tracing (PACT) Technical Report #3, (December 8, 2020), accessed March 1, 2021, https://pact.mit.edu/simulated-automatic-exposure-notification-simaen-exploring-the-effects-of-interventions-on-the-spread-of-covid-wlogos/.

[75]Estimates of the COVID-19 asymptomatic rates vary widely by age group, according to information from CDC. Centers for Disease Control and Prevention, "Estimated Disease Burden of COVID-19," *COVID-19*, (Atlanta, Ga.: updated May 19, 2021), accessed July 13, 2021, https://www.cdc.gov/coronavirus/2019-ncov/cases-updates/burden.html.

pandemic, wait times for test results in U.S. could be a week or more.[76]

- Oxford University researchers associated with the United Kingdom studies told us that the recent rise in variant strains and vaccinations has increased uncertainty in assumptions about disease transmission.

In addition to the studies on disease spread, some studies have estimated shorter-term outcomes, such as the number of close contacts detected by exposure notification apps. In one simulation study, the findings implied that the app prompted quarantine recommendations for, at most, an estimated 5 percent more exposed contacts than manual contact tracing. However, as with the modeling studies we reviewed on disease spread, these studies of shorter-term outcomes are also subject to important limitations, such as model inputs derived from studies with limited sample sizes or national estimates applied to states or local regions.

Since we originally identified papers for our review, additional studies are now underway that suggest the use of apps can help mitigate the spread of COVID-19.[77] In addition, some states are conducting their own evaluations of the effectiveness of exposure notification apps in reducing disease spread.

4.5.4 CDC and others have highlighted the need for additional research and data

Exposure notification apps are a relatively recent public health intervention. As a result, additional primary research on the benefits and effectiveness of exposure notification apps is needed, according to CDC and other public health researchers.[78] This includes a need for primary research into the use of digital tools in conjunction with manual systems, since public health authorities are unlikely to use digital tools in isolation, according to all selected states and most literature we reviewed. Specifically:

- CDC has noted that more data are needed from preliminary implementation efforts to quantify the public health value of these apps.[79]

[76] D. Lazer, et al., "Report #8: Failing the Test: Waiting Times for COVID Diagnostic Tests Across the U.S." in *The State of the Nation: A 50-State COVID-19 Survey*, (OSF Preprints, August 2020), accessed July 13, 2021, https://doi.org/10.31219/osf.io/gj9x8.

[77] See, for example, C. Segal, et al., *Early Epidemiological Evidence of Public Health Value of WA Notify, a Smartphone-based Exposure Notification Tool: Modeling COVID-19 Cases Averted in Washington State* (June 2021), accessed July 1, 2021, https://www.medrxiv.org/content/10.1101/2021.06.04.21257951v4; and J. Masel, et al., *Quantifying meaningful adoption of a SARS-CoV-2 exposure notification app at the campus of the University of Arizona* (June 2021), accessed June 1, 2021, https://www.medrxiv.org/content/10.1101/2021.02.02.21251022v6.

[78] A. Anglemyer, et al., "Digital contact tracing technologies in epidemics: a rapid review." *Cochrane Database of Systematic Reviews*. (2020).

[79] Centers for Disease Control and Prevention, *Guidelines for the Implementation and Use of Digital Tools to Augment Traditional Contact Tracing*, version 1.0 (Atlanta, Ga.: Dec. 15, 2020).

Also, the agency has highlighted the need for more studies on the effectiveness of digital tools, including exposure notification apps, to support contact tracing and reduce the spread of infectious disease. In addition, CDC has identified a specific research need to comprehensively compare the effectiveness of manual contact tracing with exposure notification apps and has initiated work to study these issues with the Massachusetts Institute of Technology's Lincoln Laboratory, according to CDC officials.

- WHO has called for additional research on the minimum adoption levels required for these apps to be effective in light of the limited evidence to date.[80] In addition, since some populations have limited access to digital technology, WHO identified the potential for the systematic exclusion of individuals who cannot access such technologies. It called for additional research and sufficient regulatory oversight of these issues.
- Linux Foundation Public Health noted that additional research on the effectiveness of exposure notification apps is needed, since there is currently a limited understanding of the extent to which apps may have changed the course of the pandemic in the U.S.[81] The organization called for a data driven approach and research on app efficacy to help app developers and others, including the federal government, decide whether to improve apps for potential future use or abandon the approach if research showed that desired outcomes had not been achieved.

Moreover, the need for additional research on the effectiveness was identified as a challenge in President Biden's National Strategy, issued in January 2021. The strategy notes that the federal government should work with public health authorities and the private sector to collect COVID-19 data on a range of issues, including the effectiveness of contact tracing.[82]

[80]World Health Organization, *Contact Tracing in the Context of COVID-19, Interim Guidance,* February 1, 2021.

[81]Linux Foundation Public Health was founded in summer 2020 with an initial focus on helping public health authorities deploy apps based on the Google Apple system.

[82]The White House, *National Strategy for the COVID-19 Response and Pandemic Preparedness*, (Washington, D.C., Jan. 21, 2021).

5 Policy Options That Could Help Address Challenges for Future Use

We identified four policy options that, when implemented, could help address the challenges we have identified for both current and future use of exposure notification apps.[83] Policymakers could also choose to maintain the status quo—that is, allow current efforts to proceed without intervention. The relevant policymakers could include Congress, other elected officials, federal agencies, state and local governments, academic research institutions, and industry. While some challenges described in this report may be addressed through current efforts, other challenges may not be resolved, may be exacerbated, or may take longer to resolve without intervention. The four policy options are in the following areas: research and development, privacy and security, data collection and measurement, and national strategy.

5.1 Policy option: Research and development

Policymakers could promote research and development to address technological limitations.

Description

Research could seek to address the technical limitations we identified that can result in users receiving false exposure notifications, such as by improving the accuracy of the distance measurements performed by exposure notification apps. For example, apps could use additional sensors (e.g., the gyroscope and magnetometer that certain smartphones already have) or other technologies, such as ultra-wideband and ultrasound. In addition, research could examine methods for evaluating other factors that affect the risk of disease transmission, such as whether the encounter occurred indoors or outdoors.

Policymakers could promote research in multiple ways, including by providing grants to academic and research institutions or by setting up a public-private partnership. Further, the research could build off of prior and ongoing research by various entities.

Opportunities

- Research on technological limitations, such as inaccurate distance measurements, could help increase the accuracy and speed of exposure notification apps, incentivizing users to download and use them.
- Research on technologies and architectures other than those used by U.S. states could also improve the apps, for example by increasing the speed

[83] We present policy options that were within the scope of this technology assessment. This is not an exhaustive list of all potential policy options, nor are policy options intended to be recommendations to federal agencies or matters for congressional consideration. They are not listed in a specific rank or order, and we are not suggesting that they be completed individually or combined in any particular fashion. We did not conduct the detailed additional analysis that would be needed to fully implement a specific policy option or combination of options—for instance, on potential design and legal issues—nor did we assess how effective the options may be. We express no view regarding the extent to which legal changes would be necessary to implement them.

and reach of notifications. Such alternatives include GPS and centralized or hybrid data architecture.

- Partnerships with technology companies could help with integrating improvements into smartphone operating systems. These collaborations could spur further technological innovation.

Considerations

- Research into new technologies could be costly and is generally considered a long-term investment with uncertain benefits.
- The roles for government, the private sector, and academia in researching new technologies for exposure notification apps would need to be defined, planned, and coordinated to ensure that research and costs are not duplicative.
- Research may not produce cost-effective improvements, because existing apps may still be sufficiently accurate for notifying a person of potential exposure. Moreover, other alternative technologies also have accuracy limitations, and other data architectures may increase the risk of revealing sensitive user information.
- Research into new technologies based on the COVID-19 pandemic may also result in apps that are not functional for future outbreaks or pandemics. Diseases that are not transmitted through the air, such as sexually transmitted diseases, would require apps that use different methods to determine potential exposure. In addition, the continuous changes in smartphone technology would require ongoing research.

5.2 Policy option: Privacy and security standards and best practices

Policymakers could promote uniform privacy and security standards and best practices for exposure notification apps.

Description

Policymakers could support the development of privacy and security standards and best practices for exposure notification apps to ensure that these apps function as intended and that user privacy is protected. One way to do this would be to specify standards for public health authorities to ensure that personal data are encrypted when stored, and to specify limits on the types of data that can be collected and how the data may be used and disclosed. In addition, the standards could specify that the data can only be used for disease response efforts and that personal data cannot be shared with other agencies, law enforcement, or immigration authorities without a user's consent.

Another action policymakers could take is to require that standards be developed and agreed on by a broad coalition of stakeholders. Best practices could also be developed by government agencies (e.g., NIST) or the private sector.

Opportunities

- Developing and adopting uniform privacy and security standards and related best practices could help address real and perceived risks that the public's data might be misused or otherwise not appropriately protected.

- Standards developed and agreed on by a broad coalition of stakeholders could increase the likelihood of still broader stakeholder agreement and buy-in.
- Independent security and privacy assessments could evaluate apps based on these standards and best practices, and these assessments could be made publicly available.

Considerations

- Policymakers would need to balance the need for privacy and security with the direct and indirect costs of developing and implementing these standards and practices.
- Implementing these privacy requirements may require flexibility because different jurisdictions could use different technologies (e.g., BLE or GPS) and data architectures to collect and use the data.
- It could be challenging to determine how to oversee and enforce the privacy and security standards and practices.

5.3 Policy option: Best practices to measure effectiveness

Policymakers could promote best practices to increase adoption and measure the effectiveness of exposure notification apps.

Description

Policymakers could assess the approaches that states have used to increase adoption and then develop best practices based on those results. Best practices could also include standardization of the metrics collected and reported to measure effectiveness as well as the procedures for verification code distribution. The development of best practices could be led by a broad coalition of stakeholders and result in guidance to states. These efforts could help address the challenges we identified related to app adoption, verification code delays, and efficacy determination.

Opportunities

- Best practices could help state public health authorities share strategies to improve app adoption. For example, if a state found that translating the app into multiple languages improved adoption among non-English speaking people, this information could be shared with other states. Also, understanding and appealing to user motivations could promote app adoption. Further, partnering with trusted sponsors could encourage cooperation in COVID-19 contact tracing, as published by the National Academies of Sciences, Engineering, and Medicine.[84]
- Such practices could help state public health authorities by providing information on potential methods and

[84] The National Academies of Sciences, Engineering, and Medicine, *Encouraging Participation and Cooperation in Contact Tracing: Lessons from Survey Research*, (Washington, D.C.: Aug. 2020).

processes for distributing verification codes in a timely manner.

- In addition, best practices can help states to measure the effectiveness and impact of these apps. Best practices could also leverage outside knowledge to promote app adoption. More accurate measurement of app effectiveness would help public health authorities identify opportunities for improvement, both to the technology's function and to its widespread use.

Considerations

- The creation of best practices could require consensus from many public and private sector stakeholders, which can be time- and resource-intensive.
- If the best practices are not updated, they may not be relevant or useful in a future pandemic.
- In some cases, stakeholders may lack sufficient or complete information or the experience to develop best practices. If best practices are put in place without sufficient basis, it could limit further innovation.

5.4 Policy option: Enhance the national strategy

Policymakers could collaborate to enhance the national strategy and promote a coordinated approach to the development, deployment, and use of exposure notification apps.

Description

Policymakers could evaluate whether to enhance the current national strategy or a future pandemic response strategy to enable a coordinated nationwide approach to the development and deployment of exposure notification apps.[85] This could help address the challenges we identified related to the adoption of these apps and evidence of their effectiveness. An enhanced strategy could include specifying federal, state, and local roles and coordination efforts. Further, an enhanced strategy could identify what other infectious diseases (e.g., tuberculosis, measles) may be applicable to exposure notification apps in the future.

As part of this strategy, the federal government could decide to repurpose apps that were developed for state use during the COVID-19 pandemic, or use comparable technology to develop new contact tracing solutions. Policymakers could recommend a national exposure notification app that public health authorities could decide to use based on their individual needs, resulting in a generic exposure notification app tailored to state needs or a federally managed exposure notification app that is made available for states to use.

[85] The White House, *National Strategy for the COVID-19 Response and Pandemic Preparedness*, (Washington, D.C., Jan. 21, 2021).

Opportunities

- Enhanced national coordination could prompt faster deployment of apps in the future if that coordination builds upon the underlying infrastructure and leverages the lessons learned from COVID-19.
- A federally led national marketing campaign with cohesive and coherent messaging could result in wider adoption of exposure notification apps. Increased federal promotion and support of the exposure notification apps could potentially help with increasing public trust in the apps.
- A national app could allow integration of exposure notification capabilities with other disease prevention and response activities, such as test scheduling or vaccine delivery coordination.

Considerations

- Implementing a coordinated national strategy would likely have associated costs and require a source of sustained funding during and after the pandemic.
- Without clear roles and responsibilities, coordination culd be challenging. For example, coordination of groups with divergent perspectives and interests may pose challenges to defining outcomes and measuring performance and effectiveness of apps.
- It is unclear whether the public would be more or les likely to trust and use a national exposre notification app than one developed by their state government. Some states, including Virginia, Colorado, and California, have passed state-wide privacy laws. Due to the absence of a federal privacy law in the U.S., the public may be less likely to trust the federal government's privacy protections.

6 Agency and Expert Comments

We provided a draft of this report to the Departments of Health and Human Services (including CDC and NIH), Homeland Security, and Commerce, Federal Communications Commission, and Federal Trade Commission for their review. The agencies provided technical comments, which we incorporated as appropriate. Representatives from Apple, the Association of Public Health Laboratories, Google, Massachusetts Institute of Technology's Lincoln Laboratory, and MITRE Corporation also reviewed a draft of this product; we incorporated their technical comments as appropriate.

We are sending copies of this report to the appropriate congressional committees and other interested parties. In addition, the report is available at no charge on the GAO website at https://www.gao.gov.

If you or your staff have any questions about this report, please contact Karen L. Howard at (202) 512-6888 or howardk@gao.gov or Vijay A. D'Souza at (202) 512-6240 or dsouzav@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made key contributions to this report are listed in appendix III.

Karen L. Howard, PhD
Director,
Science, Technology Assessment, and Analytics

Vijay A. D'Souza
Director,
Information Technology and Cybersecurity

List of Congressional Addressees

The Honorable Patrick Leahy
Chairman
The Honorable Richard Shelby
Vice Chairman
Committee on Appropriations
United States Senate

The Honorable Ron Wyden
Chairman
The Honorable Mike Crapo
Ranking Member
Committee on Finance
United States Senate

The Honorable Patty Murray
Chair
The Honorable Richard Burr
Ranking Member
Committee on Health, Education, Labor, and Pensions
United States Senate

The Honorable Gary C. Peters
Chairman
The Honorable Rob Portman
Ranking Member
Committee on Homeland Security and Governmental Affairs
United States Senate

The Honorable Rosa L. DeLauro
Chairwoman
The Honorable Kay Granger
Ranking Member
Committee on Appropriations
House of Representatives

The Honorable Frank Pallone, Jr.
Chairman
The Honorable Cathy McMorris Rodgers
Republican Leader
Committee on Energy and Commerce
House of Representatives

The Honorable Bennie G. Thompson
Chairman
The Honorable John Katko
Ranking Member
Committee on Homeland Security
House of Representatives

The Honorable Carolyn B. Maloney
Chairwoman
The Honorable James Comer
Ranking Member
Committee on Oversight and Reform
House of Representatives

The Honorable Richard Neal
Chairman
The Honorable Kevin Brady
Republican Leader
Committee on Ways and Means
House of Representatives

The Honorable Morgan Griffith
Republican Leader
Subcommittee on Oversight and Investigations
Committee on Energy and Commerce
House of Representatives

The Honorable Brett Guthrie
Republican Leader
Subcommittee on Health
Committee on Energy and Commerce
House of Representatives

The Honorable Michael C. Burgess
House of Representatives

Appendix I: Objectives, Scope, and Methodology

Objectives

We were asked to assess smartphone applications (apps)—commonly referred to as exposure notification apps—that are intended to notify persons of potential exposure to infectious diseases. This report discusses:

- the benefits and design of exposure notification apps;
- the current level of deployment in the U.S.;
- challenges affecting their use; and
- policy options that could help address key challenges for future use.

Scope and methodology

To address these objectives, we reviewed documentation and met with officials from selected federal agencies and entities involved in providing guidance, funding research, and other efforts related to exposure notification apps. These agencies were:

- Centers for Disease Control and Prevention (CDC) and National Institutes of Health (NIH) within the Department of Health and Human Services (HHS),
- Cybersecurity and Infrastructure Security Agency, Science and Technology Directorate, within the Department of Homeland Security (DHS),
- National Institute of Standards and Technology (NIST), Federal Trade Commission (FTC), within the Department of Commerce, and
- Federal Communications Commission (FCC).

In addition, we interviewed representatives from companies involved in the development of exposure notification apps (Google, Apple, and PathCheck Foundation); public health organizations (Association of Public Health Laboratories, Public Health Informatics Institute, Council of State and Territorial Epidemiologists, Association of State and Territorial Health Officials); federally funded research and development centers (Massachusetts Institute of Technology's Lincoln Laboratory and MITRE Corporation); and academic researchers from Oxford University's Big Data Institute, Nuffield Department of Medicine. We identified these entities through our interviews and document reviews. During our interviews with officials and representatives, we discussed topics such as exposure notification app functionality; benefits of its use; levels of deployment in the U.S.; technological limitations; and challenges to its development, deployment, and use. We also obtained written responses from two organizations: the National Association of County and City Health Officials and Linux Foundation Public Health.

Further, we conducted a literature search for articles regarding exposure notification apps, including their benefits, capabilities, and challenges, as well as policy options associated with the apps. A research librarian conducted searches of various databases including Inspec, Scopus, Policy File, ProQuest's COVID-19 Research Database, and the Harvard Kennedy School's Custom Google Think Tank Search. We used synonyms of the following search terms to identify relevant articles: contact tracing, exposure notification, Google Apple exposure, application, app, system, platform, digital, mobile, smartphone. We paired these search terms with additional synonyms for privacy, security, policy, legislation, opportunities, and challenges. We considered articles that met the following criteria: published from 2016 through January 2021 in academic journals, working papers, trade journals, legislative materials, and reports by government agencies and nonprofit organizations. From the results produced by this search, we reviewed a selection of articles to provide an overview and additional context for our research objectives. We also used the results to help inform our development of an inventory of states by app deployment status, among other sources noted below.

To identify the current level of deployment in the U.S., we developed an inventory of exposure notification apps that had been deployed by U.S. states and territories as of June 2021. We developed the inventory by:

- reviewing inventories that had been developed by other organizations;[86]
- reviewing state health department websites related to COVID-19 to identify whether they identified an available app, or plans to deploy one;
- conducting Google searches; and
- reviewing Android and iPhone app stores.

We also contacted several individual states to verify their status in deploying an app. We analyzed the inventory to identify the extent to which states and territories had deployed apps, the underlying technologies used (e.g., Bluetooth Low Energy), and the use of national servers.[87] States that had an app in a pilot phase at the time of our review were included in the category of "states that had not deployed an app as of June 2021."

To obtain additional information associated with the development and use of the apps, we interviewed state public health officials from a non-generalizable sample of nine states that had an exposure notification app as of January 1, 2021: Alabama, Colorado, Connecticut, Minnesota, Nevada, North Carolina, Pennsylvania, Virginia, and Washington.[88] We selected this sample based on deployment date, geographical distribution, the number of COVID-19 cases and deaths, and app developer. We aimed for a selection of states that would allow for the selected states to provide a broad overview and context for assessing our engagement's research objectives. Because the selection was based on a non-generalizable sample, the results cannot be used to make inferences about all states that had deployed an app. We also received written feedback to structured questions from two additional states (Louisiana and Utah) that deployed apps in the later stages of our evidence collection. We also conducted a review of each of the selected states apps on both a phone using

[86]The inventories included those developed by MIT Technology Review, the Association of State and Territorial Health Officials, and the Ada Lovelace Institute.

[87]Specifically, whether states used the Association of Public Health Laboratories' National Key Server and Multi-tenant Verification Server.

[88]We considered a state as having an app if it had an official application available for download or the state officially supported an exposure notification system that exists in a smartphone operating system. As of January 1, 2021, we had identified 20 states with an exposure notification app. After we selected our sample, we learned that one additional state—Wisconsin—had deployed an app in late December 2020.

the iOS (iPhone 6) and Android (Samsung Galaxy S9) operating systems. As a part of this review, we reviewed the general functions, features, and usability of the apps. To help understand how privacy considerations applied to the apps, we examined and compared each state's privacy policies with recommended practices identified in federal guidance, such as CDC's guidelines for digital tools.[89]

In addition, to obtain perspectives from states that had not deployed an app, we collected information from a non-generalizable selection of seven states that had not deployed an app at the time of our review (Montana, Nebraska, Oregon, Rhode Island, South Carolina, Texas, and West Virginia), which included an interview with one state and written responses to a semi-structured set of questions for the other six. We selected these states based on geographical distribution, suggestions from stakeholders we interviewed, and information we gathered during our review regarding challenges certain states may have faced.

We identified policy options based on our literature review and interviews with federal agencies, the selected states, and other stakeholders, including national health organizations and researchers. We assessed each policy option by identifying potential benefits and considerations of implementing them, as identified over the course of our review. Based on the evidence collected, we identified four policy options. The list is not intended to be inclusive of all potential policy options and are neither recommendations to federal agencies nor matters for congressional consideration. They are also not listed in any specific rank or order. We are not suggesting that they be done individually or combined in any particular fashion. Additionally, we did not conduct work to assess how well they may lead to a particular outcome.

We conducted our work from November 2020 to September 2021 in accordance with all sections of GAO's Quality Assurance Framework that are relevant to technology assessments. The framework requires that we plan and perform the engagement to obtain sufficient and appropriate evidence to meet our stated objectives and to discuss any limitations to our work. We believe that the information and data obtained, and the analysis conducted, provide a reasonable basis for any findings and conclusions in this product.

[89]Centers for Disease Control and Prevention, *Preliminary Criteria for the Evaluation of Digital Contact Tracing Tools for COVID-19*, version 1.2 (Atlanta, Ga.: May 17, 2020); and *Guidelines for the Implementation and Use of Digital Tools to Augment Traditional Contact Tracing*, version 1.0 (Atlanta, Ga.: Dec. 15, 2020).

Appendix II: Exposure Notification App Adoption Rates for Selected U.S. States

As previously discussed, states may use the rate of adoption to measure the success of their efforts to promote exposure notification apps. However, officials from the 11 states in our review reported that they used differing methods to calculate adoption rates. App adoption rates can be determined by dividing the total number of smartphone downloads, or activations, (numerator) by the size of a given population (denominator). However, states use different methods for determining the denominator, which affects the adoption rates. Specifically, two states used the total state population, three used populations aged 18 or older, and three used the percent of the population with a smartphone (either age 18 or older or 18 to 65), according to state officials. These inconsistent methods impede comparative assessments across states. The following table provides information on the apps deployed by the nine U.S. states selected for our review, plus Louisiana and Utah.

Table 4: Reported exposure notification app adoption rates for 11 U.S. states, as of June 2021

State	Type (custom or Express)	App name	Launch date	Reported downloads and/or estimated activations[a] (numerator)	Reported population (denominator)	Reported adoption rate[b]
Alabama	Custom	GuideSafe™	Aug. 2020	280,000	Not provided	20%
Colorado	Express	COVID Exposure Notifications	Oct. 2020	2,511,070 The combined number of iOS and Android activations taken from several sources.	Not provided	42%
Connecticut	Express	COVID Alert CT	Nov. 2020	N/A	N/A	N/A
Louisiana	Custom and Express	COVID Defense	Jan. 2021	663,379 This includes the combined number of iOS and Android app downloads for the custom app, as well as the Android app downloads and the estimated number of activations for iOS for the Express option.	3,560,976 (18 and older) Based on U.S. Census Bureau estimate for the adult population.	19%

Minnesota	Custom and Express	COVIDAware	Nov. 2020	1,419,232 This includes the combined number of iOS and Android app downloads for the custom app, as well as the Android app downloads and the estimated number of activations for iOS for the Express option.	5,600,000 (Total population) Based on U.S. Census Bureau estimates.	25%
Nevada	Custom and Express	COVID Trace	Aug. 2020	1,202,874 This includes the combined number of iOS and Android app downloads for the custom app, as well as the Android app downloads and the estimated number of activations for iOS for the Express option.	3,100,000 (80% of state population, a proxy for the number of people with smartphones) Based on U.S. Census Bureau estimates.	49%
North Carolina	Custom	SlowCOVIDNC	Sept. 2020	854,802 The combined number of iOS and Android app downloads.	9,472,502 (18 and older) Based on North Carolina's Office of State Budget and Management estimates for the adult population.	9%
Pennsylvania	Custom	COVID Alert PA	Sept. 2020	912,863 The combined number of iOS and Android app downloads.	10,880,000 (18-65 years old) Based on U.S. Census Bureau estimates for the adult population and Pew Research Center estimates that 85% of the adult population has a smartphone.	8%
Utah	Express	UT Exposure Notifications	Feb. 2021	N/A	N/A	N/A

				Data are not tracked. However, officials estimated there were 600,000 activations in the initial phase of app deployment.		
Virginia	Custom and Express	COVIDWISE	Aug. 2020	1,100,338 This includes the combined number of iOS and Android app downloads for the custom app, as well as the Android app downloads and the estimated number of activations for iOS for the Express option.	4,253,335 (18-65 years old) Based on U.S. Census Bureau estimates for the adult population and Google and Apple statements that 80% of the adult population has a smartphone.	26%
Washington	Express	WA Notify	Nov. 2020	2,068,916 The number of Android app downloads and the estimated number of activations for iOS.	6,115,500 (18 and older) Based on Washington's Office of Financial Management estimates for the adult population and Pew Research Center estimates that 85% of the adult population has a smartphone.	34%

Legend: N/A = A state that does not track the number of app downloads or its adoption rate.

Source: GAO compilation of data from selected states, related documents, interviews and other sources. I GAO-21-104622

Notes: The "as of "date for the data provided by the states ranged from May 31, 2021 to June 11, 2021.

[a]For states using the Express option, daily activations for Android are from the Google Play app store, while the Apple activations numbers are an estimate based on counting the number of times people accessed the app's logo image and using a multiplier provided by Google and Apple to estimate the number of people who go on to install the Express option.

[b]The adoption rates were provided to us by the states; we rounded the rates up to the nearest whole number. We did not calculate the adoption rates; however, the rates can be calculated with the provided numerators and denominators for the states that provided this information.

Appendix III: GAO Contacts and Staff Acknowledgments

GAO contacts

Karen L. Howard, PhD, (202) 512-6888 or howardk@gao.gov

Vijay A. D’Souza, (202) 512-6240 or dsouzav@gao.gov

Staff acknowledgments

In addition to the contacts named above, Sushil Sharma (Assistant Director), Neela Lakhmani (Assistant Director), Eric Bachhuber (Analyst in Charge), Scott Borre (Analyst in Charge), Nora Adkins, Daniel Emirkhanian, Donna Epler, Nancy Glover, Anika McMillon, Melissa Melvin, Monica Perez-Nelson, Ben Shouse, Amber Sinclair, and Umesh Thakkar made key contributions to this report. Rebecca Gertler, Tim Kinoshita, Eleni Orphanides, and Ethiene Salgado-Rodriguez also contributed to this report.

(104622)

GAO's Mission

The Government Accountability Office, the audit, evaluation, and investigative arm of Congress, exists to support Congress in meeting its constitutional responsibilities and to help improve the performance and accountability of the federal government for the American people. GAO examines the use of public funds; evaluates federal programs and policies; and provides analyses, recommendations, and other assistance to help Congress make informed oversight, policy, and funding decisions. GAO's commitment to good government is reflected in its core values of accountability, integrity, and reliability.

Obtaining Copies of GAO Reports and Testimony

The fastest and easiest way to obtain copies of GAO documents at no cost is through GAO's website (https://www.gao.gov). Each weekday afternoon, GAO posts on its website newly released reports, testimony, and correspondence. To have GAO e-mail you a list of newly posted products, go to https://www.gao.gov and select "E-mail Updates."

Order by Phone

The price of each GAO publication reflects GAO's actual cost of production and distribution and depends on the number of pages in the publication and whether the publication is printed in color or black and white. Pricing and ordering information is posted on GAO's website, https://www.gao.gov/ordering.htm.

Place orders by calling (202) 512-6000, toll free (866) 801-7077, or
TDD (202) 512-2537.

Orders may be paid for using American Express, Discover Card, MasterCard, Visa, check, or money order. Call for additional information.

Connect with GAO

Connect with GAO on Facebook, Flickr, Twitter, and YouTube.
Subscribe to our RSS Feeds or E-mail Updates.
Listen to our Podcasts and read The Watchblog.
Visit GAO on the web at https://www.gao.gov.

To Report Fraud, Waste, and Abuse in Federal Programs

Contact: Website: https://www.gao.gov/fraudnet/fraudnet.htm
Automated answering system: (800) 424-5454 or (202) 512-7470

Congressional Relations

Nikki Clowers, Managing Director, ClowersA@gao.gov, (202) 512-4400,
U.S. Government Accountability Office, 441 G Street NW, Room 7125, Washington, DC 20548

Public Affairs

Chuck Young, Managing Director, YoungC1@gao.gov, (202) 512-4800
U.S. Government Accountability Office, 441 G Street NW, Room 7149, Washington, DC 20548

Strategic Planning and External Liaison

Stephen Sanford, Managing Director, spel@gao.gov, (202) 512-9715
U.S. Government Accountability Office, 441 G Street NW, Room 7B37N, Washington, DC 20548