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Contact-Tracing Apps as Boundary Objects of Pandemic Governance: The State-by-State Approach to Contain the Spread of COVID-19 in the United States

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Digital contact tracing has been claimed as imperative to controlling the spread of COVID-19. However, the state-by-state approach in the United States led to divergences in contact tracing. This study analyzed contact-tracing apps as "boundary objects" through which each state worked toward the governance of the pandemic without having a formal consensus. Through media coverage and walkthrough analyses of three digital contact-tracing apps in Alabama, California, and New York, we closely investigated both convergences and divergences of the apps. In the process, we located the implications of Google/Apple's Bluetooth-based exposure notification system for digital contact tracing within and beyond state boundaries. Our findings suggest that the development of apps shared the notion of an ideal contact-tracing method—exposure notification—while each state was also situated in their local experiences of the pandemic as reflected in distinct app features. We further discuss the implications of techno-solutionist standardization of such digital contact-tracing apps.

Keywords: COVID-19, contact tracing, mobile apps, walkthrough, boundary object, sociotechnical assemblages, pandemic governance

On the outbreak of the COVID-19 pandemic, contact tracing has been claimed as the key to controlling the spread of the virus. Among diverse approaches, utilizing digital technology such as smartphone applications is claimed as a viable solution for effective contact tracing (Ferretti et al., 2020). Countries such as Singapore and South Korea have been relatively successful in performing nationwide contact tracing through the help of digital technologies (e.g., smartphone apps, QR code check-in systems,

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GPS tracking). Yet nationwide contact tracing has not been implemented in the United States. Although the Centers for Disease Control and Prevention (CDC) provides general guidelines, each state is left to devise its own approach, and some state governments have launched digital contact-tracing apps to facilitate statewide tracing. In May 2020, Apple and Google announced that they jointly developed a Bluetooth-based API system that enables anonymous contact tracing without collecting personally identifiable information. Numerous local governments started adopting this technology, and more than 20 states launched digital contact-tracing apps by the end of 2020. These state-by-state approaches, although all aiming for digital contact tracing, diverged in terms of the specific features they offered because each state could use the Google/Apple system to develop their own apps.

Although the development of contact-tracing apps is premised on the technical effectiveness or cost efficiency of these technologies, people have raised concerns about privacy (Redmiles, 2020; Zhang, Kreps, McMurry, & McCain, 2020). Considering that the United States lacks federal privacy legislation and that contact-tracing apps are mostly developed in partnership between state authorities and private sectors, people are concerned about the potential misuse of health data collected through these apps and the long-term problems such as increased surveillance, exclusion/discrimination, and self-disciplining (Rowe, 2020). Moreover, some apps are evolving not only to trace contact but also to connect their symptom-check feature to organizational partners so they can be further used as passports to access workplace or public spaces. As such, it is critical to investigate how these apps play a role as a "boundary object" (Star, 2010; Star & Griesemer, 1989) through which we can better understand how the governance of a pandemic has been embodied in similar and/or different ways by a various set of stakeholders involved in digital contact tracing.

This study explores such convergence and divergence across the U.S. digital contact-tracing apps as manifestations of a sociotechnical assemblage. Applying the walkthrough method, this study analyzes three apps—CA Notify (California), COVID Alert NY (New York), and GuideSafe (Alabama)—that utilized the same technology (i.e., Google/Apple Bluetooth-based technology) but were rolled out at different times during the pandemic and incorporated varying functionalities. Moreover, by analyzing media coverage on these three apps, we investigate both the apps' technological affordances and their social meanings in the context of pandemic governance. In doing so, we pay attention to the types of features that were common across the apps or distinctive in particular apps to unpack how the contact-tracing apps as boundary objects allowed different actors to envision and act on the governance of the pandemic while not necessarily having control over what digital contact tracing should entail. Our findings suggest that the development of each app is constituted through both a shared notion of ideal contact tracing and the local experiences of the pandemic. We further discuss the implications of the convergence and divergence among the apps in relation to standardization going forward.

Digital Contact Tracing as a Boundary Object

In this article, we apply the concept of "boundary object" (Star, 2010; Star & Griesemer, 1989) as we explore the convergence and divergence of the U.S. digital contact-tracing apps introduced across U.S. states. The original concept was suggested in the context of scientific work where heterogeneous actors who are embedded in complex institutional settings manage to work toward the "need for generalizable findings" despite tension emerging from their divergent viewpoints (Star & Griesemer, 1989, p. 387). From here, the analytical

framework of "boundary object" developed, referring to "a sort of arrangement that allow [sic] different groups to work together without consensus" (Star, 2010, p. 602). Boundary objects are "plastic enough to adapt to local needs and the constraints of the several parties employing them" but at the same time "robust enough to maintain a common identity across sites" (Star & Griesemer, 1989, p. 393). Star and Griesemer (1989) particularly elaborated on four types of boundary objects: (1) "repositories," (2) the "ideal type," (3) "coincident boundaries," and (4) "standardized forms" (pp. 410–411).

Digital contact tracing in the form of mobile apps falls under the "ideal type" of a boundary object. It is flexible enough to adapt to the needs of different countries and different states within a country (e.g., the United States), where each party has created its own visions of what digital contact tracing means and what it should cover. At the same time, it serves as a means of "cooperating symbolically" (Star & Griesemer, 1989, p. 410) because different parties share a common goal to contain the spread of the virus through digital technologies. Digital contact-tracing apps, then, can be deemed boundary objects with which diverse actors are embodying the notion of ideal contact tracing. These apps not only offer features where information about individuals gets captured (e.g., self-reported symptom check, sharing of Bluetooth-based codes for exposure notification) but also provide COVID-19–related information to the individuals (e.g., testing location, case statistics, social distancing guidelines). Here, privacy can be an area where the tension between personal data collection and critical information sharing is mediated. Individuals have concerns about sharing their data with authorities in crises for misuse and long-term effects (French & Monahan, 2020; Sharon, 2020); pro-privacy technology and informative privacy policy can be offered by authorities to protect individuals' rights while convincing them to share their data (Baik & Jang, 2022). The choice of a boundary object is a "political act" that maintains or redefines a collective action (Kimble, Grenier, & Goglio-Primard, 2010), and these objects embed ideological messages that result in the success or failure of its adoption (Fox, 2011). Likewise, the selection of a particular type of contact-tracing technology (i.e., Apple and Google's exposure notification system) and its representation (i.e., app features) is imbued with the aspirations of the authorities deploying it.

As Star (2010) illustrated, "boundary objects begin to move and change into infrastructure, into standards" when the "movement" between oscillating forms of boundary objects either "scales up or becomes standardized" (p. 605). However, the evolution of contact-tracing apps not only involves the standardization of a boundary object but also is shaped by "localisation processes" that can "occasion a renegotiation of standards" (Allen, 2014, p. 816). More importantly, the localization of contact-tracing apps can be seen as a manifestation of a distinctive imaginary of pandemic governance. We build on the concept of "sociotechnical assemblages," which is enacted through both digital processes and the perceptions and practices of social factors surrounding and mediating it (Christin, 2017; Liu & Graham, 2021; Seaver, 2017). Because the development of contact-tracing apps is initiated by state governments, the state's techno-optimistic vision (Avle, Lin, Hardy, & Lindtner, 2020), prioritized values, and localities significantly influence the app's functionality and interface. However, this is not the sole factor influencing the app. Rather, these apps are intertwined with the different stakes of diverse social actors including political actors (e.g., state government, local health department), commercial actors (e.g., tech company, research lab), and its anticipated users, making it a complicated sociotechnical assemblage. For instance, as users' privacy concerns are hindering the wide adoption of contact-tracing apps (Zhang et al., 2020), political and

commercial actors have been striving to mitigate these concerns by incorporating privacy-enhancing technologies such as encryption and decentralized data storage.

Even though it has been more than two years since the first statewide contact-tracing app was rolled out (i.e., COVIDWISE in Virginia), there has been a dearth of studies critically examining the social elements and co-constitutive understandings entangled with this technology. Liu's (2021) recent study analyzed China's contact tracing and risk assessment system (i.e., Health Code) as a sociotechnical assemblage and elicited how "political pressures, commercial incentives, interpersonal relationships, and regional affinities" are involved in the process of implementing a nationwide contact-tracing system in China (pp. 19–20). As the United States takes a distinctive approach, a patchwork of local governments, the design and functionalities of each app may differ from state to state, although the three apps we analyze (i.e., CA Notify, COVID Alert NY, GuideSafe) use the same Exposure Notification System API built by Google and Apple. By applying the analytical framework of "boundary object" and examining the embedded elements as sociotechnical assemblages, this article aims to interrogate how different understandings and aspirations of pandemic governance are manifested in the app designs.

Method

This study holistically examines both users' experiences simulated through a walkthrough method as well as the perception and aspirations of the developers and local governments manifested through the design of the contact-tracing apps. To better capture the co-constitutive understandings reflected in contact-tracing apps, this study additionally analyzes how contact-tracing apps are discussed in media coverages in relation to diverse social actors.

For our primary analysis, we employed a walkthrough method that is based on the cognitive walkthrough technique as a usability inspection method for interface analysis and also incorporates theoretical frameworks of science and technology studies (STS) and cultural studies. App inspection methods such as walkthroughs are analytic techniques grounded in human-computer interaction (HCI) research that can be used to evaluate interfaces without involving empirical techniques such as user feedback or usability testing. By employing the cognitive walkthrough method, evaluators approach an interface by walking through a series of pre-established tasks. The tasks are based on perceived user needs, and the interface is henceforth experienced from the perspective of the user, focusing on the learnability of a system (Lewis, Polson, Wharton, & Rieman, 1990).

Although there has been a rapid increase in the use of smartphone apps, their technical closure (e.g., lack of access to algorithms) poses a critical challenge to media researchers (Light, Burgess, & Duguay, 2018). Some scholars have introduced alternative approaches toward digital media, focusing more on the sociocultural meaning of technologies rather than merely collecting data through computational tools. Among those approaches is the walkthrough method that Duguay (2017) summarizes as closely reading the interface as "texts" (Frabetti, 2012), identifying discourses embedded in the apps' "architecture" (Papacharissi, 2009), and uncovering the "technicity" through which "human-technical relations" are transformed (Crogan & Kennedy, 2009, p. 109). Duguay (2017) applies a walkthrough in her examination of technological influences on app authenticity and grounds her hybrid-theoretical framework in Latour's

(2005) actor-network theory (ANT) and Callon's (1984) sociology of translation. Duguay (2017) assesses how Tinder constructs an actor-network and finds that it establishes authenticity through users' Facebook profiles, thereby alleviating concerns about the identity of potential matches. Light et al. (2018) build on this approach and formulate the walkthrough method as a means of establishing an app's environment of expected use by describing its vision, operating model, and modes of governance. Comparable to the original cognitive walkthrough, they first step through the various stages of an app (i.e., registration, use, end of use) while observing and documenting each encountered screen, feature, and app activity. On this foundation of data obtained via the walkthrough, the authors then build a more detailed analysis examining the app's purpose, embedded cultural meanings, and ideal users and usages.

These interpretive aspects of the walkthrough method are underpinned by the theoretical frameworks of STS and cultural studies. This differentiates the approach from traditional usability inspection methods, cognitive walkthroughs in particular, as the lens for app analysis is not so much learnability and ease of use, but cultural meanings and governance. The analytical power of this framework lies in identifying connections between contextual elements and the app's technical interface.

Applying the STS grounded walkthrough method, this article analyzes contact-tracing apps in terms of their interface, textual content, and visual aspects. The analysis uncovered the hidden affordances and social meanings embedded in these apps. Among dozens of statewide contact-tracing apps, we selected three—CA Notify (California), COVID Alert NY (New York), and GuideSafe (Alabama)—to include regionally diverse cases ranging from the East Coast to the West Coast (see Table 1). The number of downloads was also taken into consideration to choose apps that resulted in relatively high adoption rates, which can increase the possibility of capturing enough interactions among multiple stakeholders. All three apps utilized the Google/Apple Exposure Notification System based on Bluetooth technology, yet they were rolled out at different times of the pandemic, likely leading to nonidentical perspectives and experiences (see Figure 1).

Table 1. Overview of Three U.S. Contact-Tracing Apps.

Contact-Tracing App	State(s)	Technology	Developer	Rollout Date	Number of Downloads[b]
GuideSafe	Alabama	Bluetooth	MotionMobs & University of Alabama at Birmingham	Aug 16, 2020	100,000+
COVID Alert NY	New York	Bluetooth	New York State Department of Health	Sep 30, 2020	500,000+
CA Notify[a]	California	Bluetooth	CA Dept of Technology	Dec 10, 2020	500,000+

[a]The Android version is available as a standalone app on Google Play; CA Notify for iOS is embedded into iPhone device settings.
[b]Collected from Google Play on January 15, 2021.

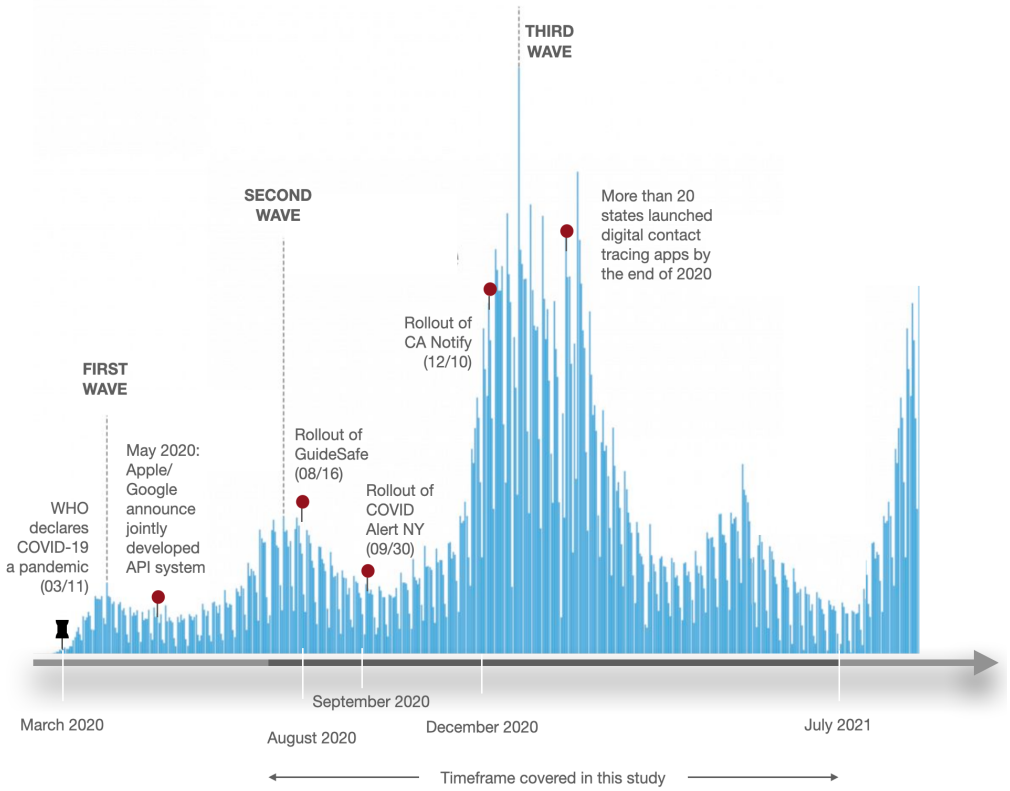

Figure 1. U.S. COVID cases (Mitropoulos, 2021) overlayed with dates relevant to our study.

We started out with a standard cognitive walkthrough framework, in which we defined the users and their goals as well as the tasks they would attempt. The users for each app are local to the state in which it is available; no other restrictions apply. The main goal of a COVID-tracing app is to enable users who have tested positive for COVID-19 to share that information so others in their vicinity may be warned. We identified the anticipated user tasks for the contact-tracing apps as follows: Sign up, report positive test results, understand privacy policy, complete a symptom check, report current status to organizations, inform oneself about preventative measures, browse local COVID statistics, find testing sites, share app to friends, and understand terms of service.

We then independently evaluated each of the interfaces by walking through the apps step-by-step based on the tasks defined earlier and capturing the experience through the lens of the user. Along the way, each of us took screenshots of the interface and took notes of our observations as we attempted to complete these tasks. We recorded any paths we would take as well as the terminology we would use and how that compares to the way it is presented in the app. This allowed us to simulate and analyze the lived experience of users, which is lacking in previous literature. We then organized the findings according to two big themes: (1) convergence of the apps based on common features they offer and (2) divergence of the apps manifested in additional features not every app provides to users. Common features across apps included sign-up

processes, privacy policies, and reporting of test results and exposure notifications. There were also divergences in some features across the three states such as symptom checks and their organizational usage, COVID statistics, preventative measures, and test site information.

Despite its strength in unveiling cultural meanings, the walkthrough method that this research deployed also has shortcomings. Unlike empirical techniques such as experiments, usability testing, surveys, or user interviews, we did not trace actual users' reactions. Thus, it is difficult to capture the actual response or interpretation of the apps' users and observe how they use these apps in their everyday lives. Moreover, the user's interpretations may differ according to their personal backgrounds including age, race, gender, socioeconomic status, political ideology, and so on, which may not be detected through the walkthrough method. We also acknowledge the limitation of our analysis that arises from our positionality as communication scholars who are more adept at mobile technology and technical jargon and as individuals from developed countries. Although some scholars have raised ethical concerns such as disturbing the user dynamics with a dummy account or unintentionally recording other users' information in the process of a walkthrough (Dieter et al., 2019), our research did not involve interpersonal interaction with other users. Furthermore, to prevent any confusion in real-life contact tracing, accounts created for this study did not make use of verification codes for positive tests so as to not falsely send exposure alerts to other people, and accounts were deleted as soon as data collection was completed.

In addition to the walkthrough method, this study conducted a qualitative analysis of media coverage on the three contact-tracing apps as well as the update history of each app. This helped us better understand the visions and aspirations of the developers and governing entities surrounding this technology, which is difficult to be captured solely by the walkthrough method. The news articles were searched from the LexisNexis Academic database using each app's name as keywords. The search was limited to news articles geographically tagged as "North America" and published during our analytical time frame (from August 1, 2020 to July 31, 2021). App update histories (since their respective rollout dates until July 2021) were collected from the App store, except for CA Notify, which does not have a standalone app on the App store.

Convergence Among Contact-Tracing Apps

Emphasis on Privacy Throughout the Sign-Up Process

The main convergence identified across the apps is the emphasis put on the protection of privacy throughout the sign-up process in offering instructions on how the technology works and how to use it. Just as the media coverage of all three apps frequently mentioned their use of the Bluetooth-based privacy-protective Google/Apple Exposure Notification System, their in-app sign-up processes all appeared to highlight it as well. For example, CA Notify provided a few paragraphs of instructions that make clear voluntary usage, explain how the technology works, how to report COVID test results, and how it ensures data privacy before a user consents to the app use. COVID Alert NY and GuideSafe, although using more visual components such as appropriate illustrations along with textual description, similarly emphasized the privacy-protective Google/Apple contact-tracing technology throughout the sign-up process. COVID Alert NY provided a couple of paragraphs of text explaining what "close contact" means, what type of technology

it uses (Bluetooth), how close contact sensing works, and how privacy is secured. Putting more emphasis on illustrations, GuideSafe provided a few sentences describing how the app works and a few short paragraphs explaining how they protect the user's privacy. Interestingly, GuideSafe dramatically revised its visual aspects through a major update during our analysis period, still making the protection of privacy prominent at the top of the screen (see Figure 2).

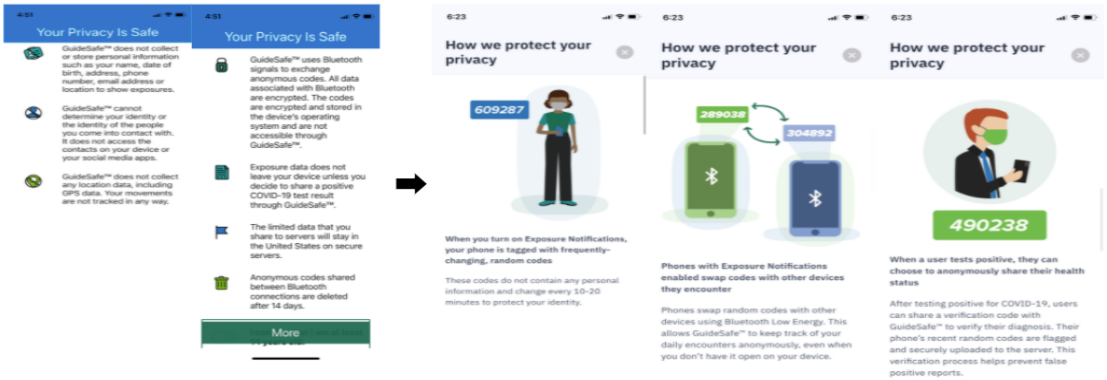

Figure 2. Changes in GuideSafe's visual instruction (Alabama Department of Public Health, 2021).

Note. The changes through Version 1.10.0 were introduced in February 2021.

Although all apps promoted the protection of privacy in their apps, the level of information required from the users (e.g., consent forms) or provided by the apps (e.g., privacy policy/terms of service, instructions) slightly differed from app to app. For instance, GuideSafe and COVID Alert NY had an age requirement (of 14+ and 18+, respectively), but CA Notify did not have one. Also, COVID Alert NY did not require the users to explicitly consent to its terms of use, privacy policy, and/or terms of service, whereas CA Notify and GuideSafe required them and provided via external links in both apps during the sign-up process. At the same time, CA Notify required additional consent to "exposure notifications" to use its service. Optionally, CA Notify and GuideSafe asked for consent from the users to share personal data with the state's Department of Health to help contain the spread of COVID. In this case, the apps highlighted that the user data is collected in a privacy-protective way and deidentified or anonymized, without personally identifiable information (PII) being shared with health departments. Clarifying how data is collected and shared and requiring consent forms in advance can be interpreted as efforts to mitigate privacy concerns of the users.

Media coverage of the apps further showed that the governing entities of the apps recognized the privacy concerns raised by the users. For all three apps, there were a number of news articles promoting the privacy-protective aspect of their apps in addition to the Google/Apple technology. These articles mainly emphasized the anonymity and voluntariness of contact-tracing apps as reflected in the following quotes: "COVID Alert apps never reveal the identity of the COVID-19 positive individual" ("Governor Cuomo," 2020, para. 8), "California does not ask for supplemental information from users that could create privacy concerns" ("Best in Law," 2021, para. 10), "GuideSafe app is voluntary and is designed to protect privacy" (Foster, 2020, para. 11). Considering that many of these news articles were press releases from the local

governments or the developing entities, these articles shed light on how these entities wanted to present the technology to the public. These media coverages imply that the three states shared a similar "imaginary" or "ideal type" of privacy-protective contact tracing when developing and launching their own apps.

Privacy Policy

As much as the three apps emphasized the importance of privacy protection, they all had privacy policies. We thus observed (1) how easy it is to locate the policy, (2) how legible it is, (3) how much meaningful information it provides, and (4) whether any privacy-related laws are indicated. First, the privacy policy of each app was generally easy to locate. COVID Alert NY had its privacy policy within two clicks from the main menu tab (App Settings → Data and Privacy Policy), providing brief in-app texts as well as a link to an external page for its "comprehensive privacy policy." CA Notify (Android app) was the same (Settings → Privacy Policy), leading to an external webpage. CA Notify's iOS version worked differently because it did not have a standalone app but used the Exposure Notifications Express system available in Apple's device settings. Once a user clicked on the active region of California within the Exposure Notifications, the privacy policy was available as an external link under Legal Terms. Alabama's GuideSafe had its privacy policy within three clicks from the main menu tab (Settings → Legal → Privacy Notice) in the app, which led to an external webpage that outlines the policy. Overall, the apps provided the details of their privacy policies via external links, not necessarily offering information within the app environments.

With regard to the content of privacy policies, there were two layers to consider. First was the level of plain language used in each privacy policy, and second was the degree to which information provided by the policy is meaningful to users. The first layer did not vary much across the three apps. Every app provided a similar level of plain language, which is an advancement considering that traditional corporate privacy policies have been often criticized for their heavy use of legalese. Regarding the second layer, the three apps similarly explained personal data they do not collect. The apps emphasized that they are using Bluetooth-based contact-tracing systems and are not collecting or tracking any location information of the users. CA Notify's privacy policy explained that it does not collect or retain personal information such as location (GPS; California Department of Public Health, 2021); Alabama's GuideSafe highlighted that there is no collection of location (Alabama Department of Public Health, 2021); COVID Alert NY mentioned that it does not collect personally identifiable information (e.g., name, address), location, and any information outside the user's app (New York State Department of Health, 2021). This shows that these apps recognized location tracking to be a major privacy concern raised by their users for digital contact tracing. Meanwhile, it was COVID Alert NY that offered the most extensive set of additional meaningful information. COVID Alert NY, for example, outlined subsections of data, app metrics, how data is used, age restrictions, and resources and partners under its privacy policy. In particular, COVID Alert NY clearly identified whom it is partnered with, including project governance and delivery (i.e., New York State Department of Health, Tech: NYC), research (i.e., SUNY, Columbia University, Cornell Tech, MIT-Private Automated Contact Tracing), technology partners (i.e., Apple, Google, Amazon Web Services, and Linux Foundation Public Health), and commercial partners (i.e., NearForm, Inc). Because one of the main privacy concerns arises from the institutional entities involved in the collection, processing, sharing, and use of users' health data, such transparency matters.

Quite surprisingly, however, none of the three apps specified which privacy law(s) they were guided by or regulated under in their privacy policies, such as the Health Insurance Portability and Accountability Act (HIPAA). For example, a user of CA Notify could read information during its sign-up process and see in its legal terms that "The use of CA Notify is subject to California law" (California Department of Public Health, 2021, para. 6), but it did not mention any laws like the California Consumer Privacy Act (CCPA) that went into effect in early 2020. Alabama's GuideSafe did not identify any privacy laws in its privacy policy, yet it mentioned in the policy that "the limited data that you share with servers will stay in the United States on secure servers" (GuideSafe, n.d.-b, para. 8), alluding to the U.S. jurisdiction. The privacy policy of COVID Alert NY also did not mention any specific privacy laws. Instead, its comprehensive privacy policy provided a hyperlink to the New York State Department of Health Privacy Policy, which mentioned provisions of the Internet Security and Privacy Act, the Freedom of Information Law, and the Personal Privacy Protection Law.

Reporting of Positive COVID Test Results and Exposure Notifications

At the center of all three apps was the feature that supported reporting of a positive COVID-19 test result and exposure notifications (see Figure 3). In the case of Alabama's GuideSafe, for example, reporting a positive test was the first thing users would see when opening it. The app opened to the "Dashboard," one of three main tab bar items, and almost the entire screen was taken up by a text box with a visual that asked, "Have a positive test?" The short informational text was followed by a call to action in the form of a button labeled, "Report Positive Test" (Alabama Department of Public Health, 2021). One thing to note is that GuideSafe, as the earliest app launched among the three apps analyzed in this study, was initially focused on contact tracing of people in Alabama. However, it joined the Association of Public Health Laboratories (APHL)'s National Key Server in November 2020, acknowledging the importance of contact tracing across states. Initiated in July 2020, the APHL National Key Server aimed to enable Apple and Google's Exposure Notifications System (ENS) across the United States, lifting each state public health agency's "burden of building and hosting its own key server" (APHL, n.d., para. 3). By the time Alabama decided to join it, New York had already joined it, and California was piloting it with a limited population. Media coverage of GuideSafe described Alabama's move positively: "Connection to APHL National Key Server Extends GuideSafe(TM) App Capabilities Beyond State Lines" (Greer, 2020) and "Alabama Coronavirus App [Becomes] Part of Growing Multistate Network" (Associated Press, 2020).

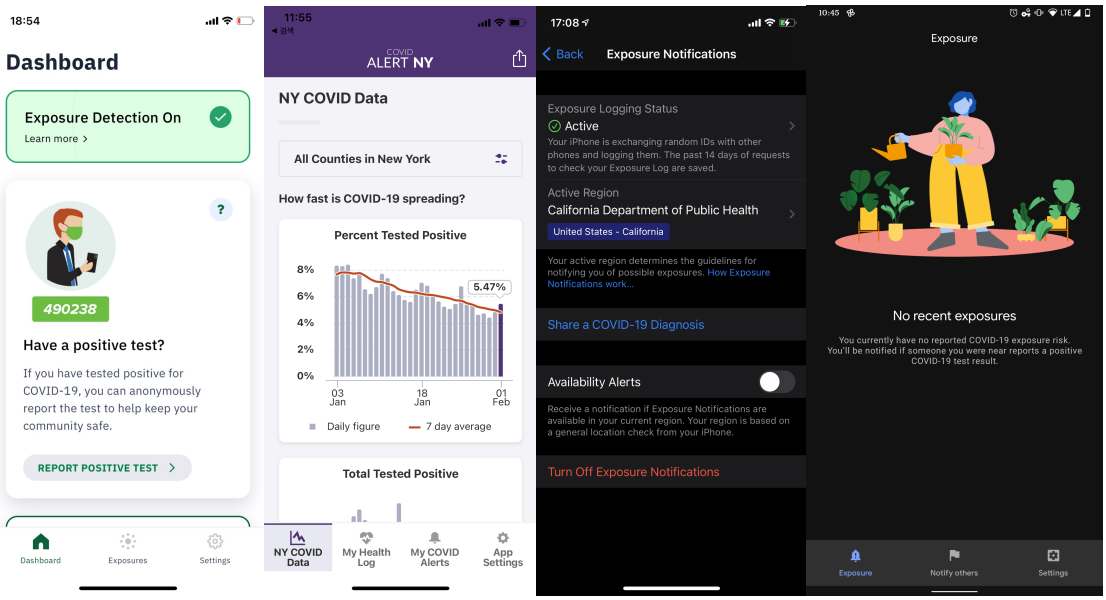

Figure 3. Left to right: Landing pages of GuideSafe (Alabama Department of Public Health, 2021), COVID Alert NY (New York State Department of Health, 2021), and CA Notify (iOS/Android) (California Department of Public Health, 2021).

Note. CA Notify for Android and iPhone are available in both light and dark mode, whereas COVID Alert NY and GuideSafe have only one version (displayed) available. Screenshot of CA Notify for Android was obtained on February 18, 2021 (before redesign of the app).

However, our walkthrough analysis of GuideSafe's COVID-19 reporting identified a critical technical issue in the verification process of test results (see Figure 4). When clicking on "Report Positive Test" and continuing through the next info screen, one would arrive on the "Test Details" page, which required a phone number and test date input, but no official test verification code. On submitting one's phone number, the user would be prompted to allow sharing of the device's random IDs. Hereafter, the user would be led to the "verification code screen." On receipt of a text message from the app, the user would be given a verification code to enter into the interface. The app asked again to share random IDs, even though this had already been allowed. A pop-up message in green proclaimed "Success!" and thanked the user for "keeping everyone safe!" (Alabama Department of Public Health, 2021) However, the app never asked for verification of a positive test result from an official medical institution, nor did it ask for the test site or other information about the positive COVID test, solely relying on the user to be reporting accurate information. More importantly, the interface also did not ask users to confirm before submitting that they were in fact setting their status to having been tested positive to make sure that users were aware the app was taking their word and was not working to sync with any official test data in the background. Any user would be able to initiate the creation of a GuideSafe verification code simply by providing a valid phone number, even if they have not been tested at all. Because no verifiable code from an official testing site was required, this app provided a very low threshold for intentional misuse and, because of missing warnings, accidental

misuse.[1] Lastly, one would expect that the app reflected the status update and confirmed the user's test report and its date. Yet this was not the case; the user interface did not change at all, and the user could even go on to report more positive tests. This indicates there were no app-internal checks applied regarding the user's status change. It also means that wrongly reported positive tests could not be taken back. This is not only a usability problem of high severity but also an ethical issue because other users could be potentially warned of a threat that did not exist, which may lead to decreased confidence in the accuracy of the app overall. This implies that there continued some divergent technical challenges for accurate and effective contact tracing at the local level, even though states developing their own contact-tracing apps were increasingly working on ways to collaborate across state boundaries through the identical Google/Apple system and coordination with APHL.

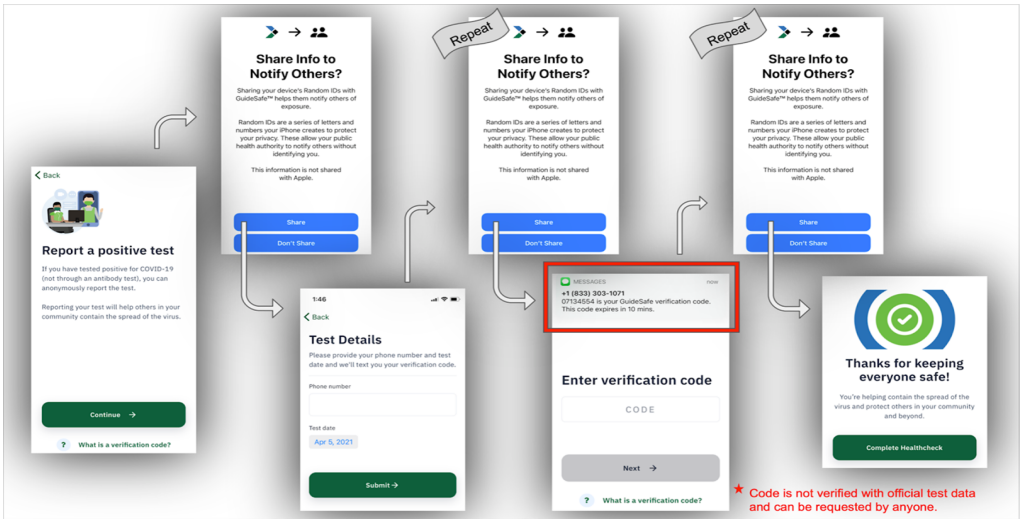

Figure 4. Reporting of a positive test result on GuideSafe (Alabama Department of Public Health, 2021).

In the case of COVID Alert NY app, it also offered COVID-19 reporting as a prominent feature. It had a CTA (Call-to-Action) labeled, "What to do if you test positive for COVID-19," located under the tab bar item "My COVID Alerts" (see Figure 3; New York State Department of Health, 2021). The message emphasized that one should stay home for 14 days and isolate oneself. The page was filled with additional text information, and it provided a button to "Share Your Close Contact Codes" at the bottom of the page. The naming differed from the other apps, though, because it did not include references to either "test," "positive," or "notify"; instead, it included the term "contact codes," which may be unfamiliar to users until they have read through the body of text on the page. On closer inspection, it became clear that these contact codes are anonymous IDs of people who recently spent more than 10 minutes within 6 feet of one's location and that they can be sent an alert if they have been near someone who tested positive. Sharing

[1] We reached out to the general contact of GuideSafe for clarification twice via email but did not hear from them until the time of analysis in July 2021. We also deleted all the data right away, erased the app, and reinstalled it after testing the feature and diagnosing the problem for the purpose of this research.

required an eight-digit number by a public health representative who is supposed to call you after you receive a positive test result at an official test site.

Reporting of COVID-19 positive cases and exposure notification was central to CA Notify. In CA Notify (Android), the screen to share a positive COVID diagnosis was one tap away from the landing page of the app (see Figure 3). As a main navigation item in the tab bar of the app, the link to reporting a positive test result was labeled "notify others" and therefore focused on its function of warning others (of exposure). Users looking for wording mentioning "test" or "positive" might not initially expect it there, but because the app design and structure were straightforward and sparse, it did not take long to go through the three navigation items at the bottom of the app; the second item ("notify others") already brought up a screen whose headline stated clearly in bold lettering to "share your COVID-19 test result" via a prominent button with the same label. A brief text explained that a test verification code, which should have been received together with the positive test results from an official test location, was needed to continue. Simply inputting the code and confirming with "verify" would complete the process. The iOS version of CA Notify featured the prompt to "share a COVID-19 diagnosis" prominently on the very first screen. This CTA was placed in the center of the landing page, in between a list of four to five other main navigation items, and highlighted in blue text to make it clear it was a link. Selecting the link led to an informational message about how CA Notify works to help notify others of exposure, from where one may continue on to enter the code to verify the diagnosis.

Summary

Our findings suggest that the core goal of contact-tracing apps across the three states was to provide digital contact tracing in a privacy-protective way. These apps appeared to have reached "agreements about methods" for digital contact tracing as a boundary object (Star & Griesemer, 1989, p. 413), using the same Google/Apple Bluetooth-based technology and providing somewhat standardized privacy policies. All three apps highlighted the importance of privacy throughout the sign-up process, explaining how the apps would protect personal data through such a technology; they required consent in advance to enter these apps (even if to varying degrees), and they made their privacy policies generally easily accessible. Media coverages also reflected how local governments and developers were envisioning an ideal way of conducting privacy-protective contact tracing through these apps. Over time, all three apps also became part of the APHL National Key Server, which was expected to facilitate contact tracing across states. Although there were several ongoing limitations such as little specification of privacy law(s) under privacy policies and false-positive test result verification (i.e., GuideSafe), the functionality of reporting positive cases and notifying exposures while protecting privacy was the key affordance promoted and embodied across the three apps.

Divergence Across Contact-Tracing Apps

GuideSafe's Focus on Organizational Usage

Although three apps developed for Alabama, New York, and California all treated reporting of COVID-19 positive test results and exposure notifications as their key affordance, digital contact tracing as a boundary object simultaneously allowed divergences across the apps to an extent. Alabama's

GuideSafe was particularly keen on offering symptom checks and accommodating organizational use of those results (see Figure 5). In fact, GuideSafe's "Healthcheck" and "event passport" were almost always introduced as main features along with exposure notification in media coverage. GuideSafe users could access Healthcheck by clicking on an external link (i.e., "Healthcheck"). Once a user is on the Healthcheck website, they can further link their data with participating organizations, or to a COVID research database (www.helpbeatcovid19.org). That is, GuideSafe was encouraging users to report their symptoms and share them with organizations they were part of when necessary and for public health research. Approximately 40 organizations including schools and colleges were listed on this external website as of July 2021.

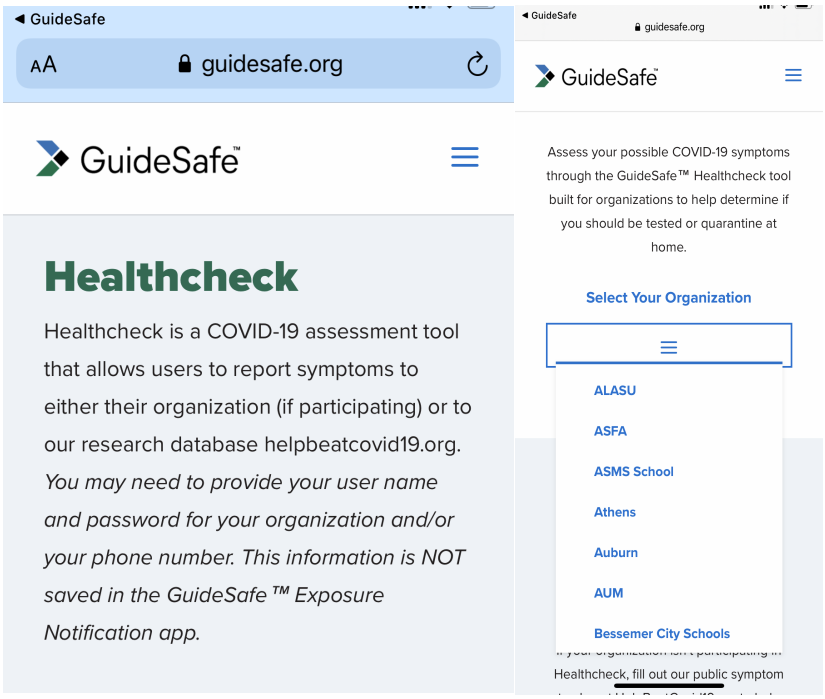

Figure 5. GuideSafe's Healthcheck and organizational use (GuideSafe, n.d.-a).

Such a heavy focus on the organizational use of GuideSafe can be explained in part by the partnerships with local universities it drove during the first several months of the app launch in specific. From the beginning of its development, the University of Alabama at Birmingham was playing a key role, and the pilot testing of the app invited college students across Alabama to participate before it became available to the general public. Moreover, GuideSafe meant not only the app but also a statewide initiative that mandated entry testing of COVID-19 for all college students in Alabama before the start of the fall semester in 2020 (Foster, 2020). Once the fall semester of 2020 started, GuideSafe entry testing turned into sentinel testing of COVID-19 for randomly selected students/faculty/staff across colleges in Alabama. As such, the higher-education setting was a key part of Alabama's approaches to digital contact tracing, and this was well reflected in the features highly encouraged by the GuideSafe app accordingly.

COVID Alert NY's Information-Oriented Approach

COVID Alert NY, compared with the other two apps, was most actively offering additional information-oriented features, including information about preventative measures, COVID-19 statistics, and testing site locations. When it comes to information about preventative measures, for example, the COVID Alert NY app provided detailed guidelines within the app interface under "Learn how to keep others safe," which can be found after tapping on the third tab bar item "My COVID Alerts" (New York State Department of Health, 2021). The list of recommendations to follow (until one has been cleared by a medical professional) included the following: "Stay home," "Call ahead if you must leave to get health care," "Separate yourself," "Don't have visitors," "Use a separate bathroom," "Have food brought to you," "Cover your coughs and sneezes," "Don't touch pets," "Arrange for others to care for your children, if possible," "Wash your hands," "Get tested," "Monitor your temperature and symptoms carefully," and "Call the Hotline" (numbers are provided; New York State Department of Health, 2021). The COVID Alert NY app offered the most detailed guidelines and contact information, whereas GuideSafe offered sparse information and an external link, and the CA Notify apps (Android and iOS) did not provide any preventative guidelines in the app.

Another outstanding feature available in COVID Alert NY was statistical information about the pandemic. It was the first of four-tab bar items its users would land on, titled "NY COVID Data" (see Figure 6). The location selector was set to "All counties in New York," and visually prominent graphs depicted how fast COVID-19 was spreading. The first visualization showed "Percent tested positive," followed by "Total Tested Positive" and "Total Persons Tested." Additional testing data was available via an external link to the New York State Department of Health, which opened a Tableau Tracker map. Moreover, a vaccine tracker was linked externally. It was only COVID Alert NY that featured such statistics prominently (on the first page that users see); neither of the other apps in Alabama and California did so.

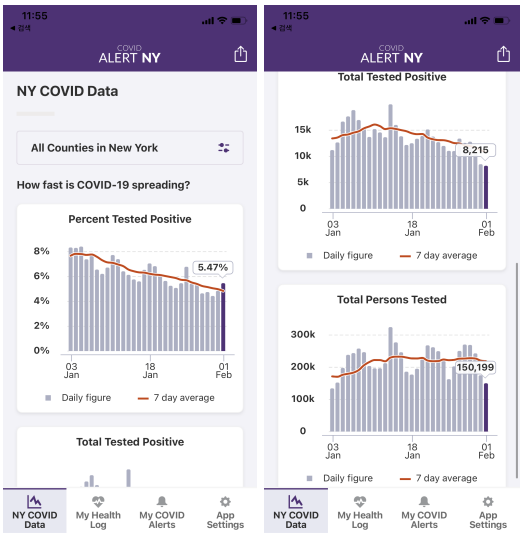

Figure 6. Statistics in the COVID Alert NY app (New York State Department of Health, 2021).

Relatedly, most apps were not set up to provide any testing site information, whereas only COVID Alert NY mentioned test sites within the app and then provided an external link to the actual locations. COVID Alert NY's third tab bar item "My COVID Alerts" provided an option titled "Learn how to keep others safe," which led to a list of recommendations (New York State Department of Health, 2021). Scrolling below the fold revealed the option "get tested" together with an external link to "find a test site near you" (https://coronavirus.health.ny.gov/find-test-site-near-you). All these information-oriented features offered by COVID Alert NY can be understood in the context of New York State's experiences of the pandemic during 2020. New York was the state that went through the first big outbreak in the United States, and the evolving status of New York was frequently portrayed to the public's eyes with corresponding numbers such as infection rates, death tolls, and ICU capacity. This could have likely contributed to COVID Alert NY app's focus on providing statistics and detailed health guidelines to the users.

CA Notify's Embracement of Exposure Notifications "Express"

Whereas the two apps from Alabama and New York presented additional features, California's app CA Notify did not, centering its functionality around facilitating positive results reporting and exposure notification. The main reason for this is because it embraced the Exposure Notifications "Express" system of Google/Apple technology from the beginning. In the media coverage of CA Notify, it was often highlighted that iPhone users do not need to download any app and could simply activate Exposure Notification in their iPhone's Settings. Even though Android users still had to download the CA Notify app because of the technical difference between Apple and Google, the app was very much minimalistic, providing only the features where users can check whether they have been exposed to COVID-19 or report their positive test results.

Summary

Divergences across these contact-tracing apps in three different states imply that each state's experience or understanding of the pandemic was not always identical, leading to the implementation of features that fit particular local needs. Also, because the apps were launched in varying stages of the pandemic, different iterations of the Google/Apple technology were used in building the apps. Thus, GuideSafe and COVID Alert NY developed standalone apps using Google/Apple's initial technology, with GuideSafe prioritizing organizational use of symptom checks and COVID Alert NY offering additional information-oriented features. Meanwhile, CA Notify, which was developed the latest among three apps, used the next iteration of Google/Apple technology, Exposure Notifications Express, from the start and made exposure notifications the central and only piece of its functionality. This shows digital contact tracing worked as a boundary object, "plastic enough to adapt to local needs and the constraints of the several parties employing them" (Star & Griesemer, 1989, p. 393).

Discussion and Conclusion

Our findings from the analysis of three contact-tracing apps in the United States suggest that the apps were functioning as boundary objects (Star, 2010; Star & Griesemer, 1989), allowing various social actors to work on digital contact tracing and develop attendant mobile apps without necessarily having consensus (see Figure 7). Digital contact tracing in the United States has been a patchwork of different apps

without any federal-level mechanism, and these apps did not start with formal consent between state governments. They rather stemmed from local actors' visions and aspirations for digital contact tracing. Yet the Google/Apple Bluetooth-based technology adopted by most of these state apps (including all three apps analyzed in this study) worked as "agreements about methods" for digital contact tracing as a boundary object (Star & Griesemer, 1989, p. 413). This technology enabled various state actors to work on the introduction of contact tracing (1) in a privacy-protective way and (2) through the exposure notification system. In the introductory period of contact-tracing apps in Alabama, New York, and California, their use of the Google/Apple Bluetooth technology was repeatedly highlighted in media coverage as a way to trace contact effectively while protecting individuals' privacy. The protection of privacy was consistently emphasized across three apps' interfaces as shown in our walkthrough analysis. All three apps promoted privacy throughout their sign-up processes and worked toward relatively user-friendly privacy policies. The emphasis put on privacy was integral to the central feature offered by these apps: reporting of positive test results and exposure notifications.

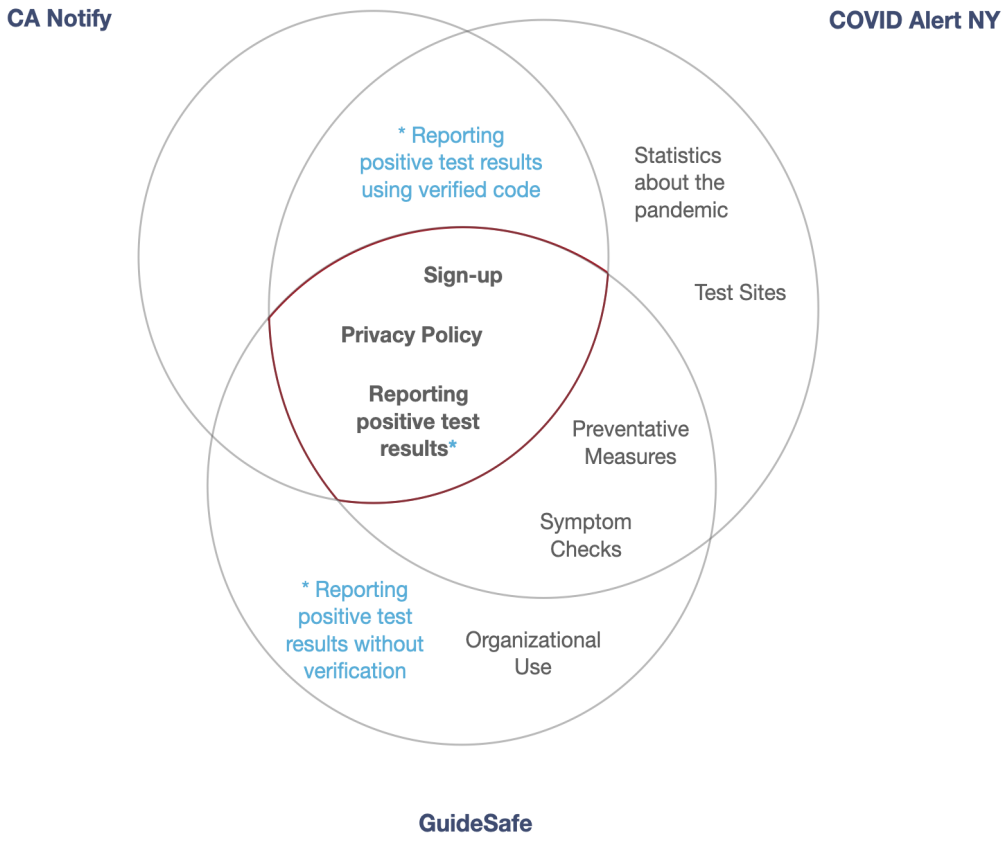

Figure 7. Divergences and convergences of the three contact-tracing apps.

Despite these commonalities, we also observed divergences in contact-tracing apps. Such divergences are mainly because of localities and varying situations surrounding this technology. The

geographic spread of the pandemic and its severity were mirrored in the way each state's app offered particular features. For instance, Alabama was one of the earliest states that developed a digital contact-tracing app, and the app's functionality was heavily focused on the organizational use of test results, in part because of a parallel statewide mandatory testing initiative at local colleges and universities that was in action. Meanwhile, New York state experienced the first big outbreak in the United States and dominated headlines for months, with heightened public attention paid to numbers such as infection rates, death tolls, and ICU capacity. This corresponds to COVID Alert NY app's focus on statistics and detailed health guidelines. In other words, New York's devastating experiences in the early months of the pandemic might have prompted New York to approach digital contact tracing in a more information-oriented manner. In contrast, California had much more time to prepare before the pandemic began to spread in the region to a similar extent; it adopted Google/Apple's Exposure Notifications "Express" system that became available at the time of its development, which facilitated a much more simplified interface. As such, variance in app designs implied social actors' divergent perceptions and experiences of the pandemic in local contexts.

Indeed, there were constant balancing acts between the convergence and divergence of the apps. For example, state contact-tracing apps started to join APHL National Key Server as they recognized the increasing need for interoperability of digital contact tracing across state borders, an effort that can be perceived as a way to mitigate differences across apps. Here again, Google/Apple Bluetooth-based technology facilitated such coordination. Although interoperability is critical for successful digital contact tracing, we suggest that standardization may have its own disadvantages. As Google/Apple's exposure notifications system evolved from offering an API to offering a ready-made notification feature (i.e., exposure notification express), the functions that catered to local needs and contexts were lost. In fact, COVID Alert NY decided to discard the standalone app in June 2022 and adopted the exposure notification express for iOS devices, sunsetting information-oriented features.[2]

We suggest that the unintended consequences of such techno-solutionist standardization merit further investigation. Google/Apple's Bluetooth-based technology started off as a contact-tracing method that facilitated different states' development of apps addressing individuals' privacy concerns across states. However, its standardization around exposure notification has led to the loss of local contexts and textures (e.g., providing local information or facilitating organizational uses), which could have fallen short in meeting each state's residents' local needs during the pandemic. Future studies capturing the experience or interpretation of actual users could further speak to these issues. Still, contrary to the earlier optimism, digital contact tracing was not adopted widely enough across states, receiving mixed evaluations of whether it actually worked in the United States (Ladyzhets, 2021). The success or failure of a boundary object depends on the reception of the social meanings and relations embedded in the object (Fox, 2011), and the United States' digital contact tracing can be considered to have failed to become a boundary object-in-use in that sense. We believe our study contributes to understanding the nonlinear changes U.S. digital contact-tracing apps went through as boundary objects over time, shedding light on some of the key local dynamics.

[2] This was not included in our formal analysis because it occurred after our analysis period.

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