Designing Information Systems for Infectious Disease Management VUCA Situation: Insights from a Design Archaeology Analysis of COVIDSafe

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Designing Information Systems for Infectious Disease Management VUCA Situation: Insights from a Design Archaeology Analysis of COVIDSafe

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Abstract

Experience from contact tracing information systems (IS) relating to COVID-19 show that designing IS to manage infectious diseases in volatile, urgent, complex, and ambiguous (VUCA) situations requires navigation of the interplay between several factors: technical features, the challenges of optimizing timeliness, sensitivity, public value, the urgent need for mass adoption, and unprecedented privacy, trust, and ethical dilemmas. In this paper, using a design archaeology approach, we analyzed the historical, stakeholder, artifactual, aesthetic, instrumental, and symbolic dimensions of COVIDSafe – a contact tracing IS implemented by the Australian Government. Based on the findings, we embarked on design theorizing, moving from the specific instance of the COVID-19 pandemic and COVIDSafe to the broader problem of VUCA health situations and solutions (i.e., infectious disease management information systems (IDMIS)). We contribute a new design theory for IDMIS specifying the aims and scope of the future design efforts for which the design theory can be useful, the roles of different stakeholders, and a set of design principles that clearly define actors, contexts, mechanisms, and rationale. We also discuss the usability of our inductively developed theory. Normatively, we add to the descriptive and explanatory knowledge that promotes a greater understanding of the role of IS in controlling and managing infectious diseases. In terms of method, the study highlights the application of a design archaeology approach for IS design theory research.

Keywords: COVID-19, COVIDSafe, Contact Tracing, Design Theory, Design Archaeology, Infectious Disease Management, Information Systems, VUCA.

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1 Introduction

The outbreak of COVID-19 presented a volatile, uncertain, complex, and ambiguous (VUCA) (Bennett & Lemoine, 2014; Horney et al., 2010) situation for both society and information systems (IS) design and research. It was *volatile* due to the rapid spread of the virus, its mutation, and the number of deaths occurring in different countries. It was *uncertain* because scientists and public health officials had limited knowledge about the epidemiology of the virus and how to effectively control it. The situation was *complex*, involving epidemiological, public health, technological, economic, and political decisions at a scale very different from either the 2002/2003 SARS, the 2009 swine flu, or the 2014 Ebola outbreaks. Furthermore, it was *ambiguous* as there were no proven solutions for controlling the spread of the virus, despite prior research (Bravata et al., 2004; Clements, 2009; Hopkins, 2005) and World Health Organization (WHO) guidelines on public health surveillance systems.. The lack of available approaches was particularly true for designing contact tracing IS (CoTIS).

CoTIS in the context of COVID-19 are IS instantiations for the management of a VUCA situation. A CoTIS can be described as a sociotechnical IS for identifying people who have been in contact with infected individuals during an infectious disease outbreak, with the subsequent purpose of testing, quarantining, and treating them to limit community transmission (Ferretti et al., 2020; WHO, 2020). CoTIS is a sub-category of infectious disease management information systems (IDMIS). These are sociotechnical systems (De Leoz & Petter, 2018) that help public health agencies and other organizations to collect, analyze, monitor, and manage infectious diseases that occur either naturally or due to bioterrorism (Chen et al., 2011).

At the onset of the COVID-19 pandemic, most public health systems relied on ineffective manual contact tracing (Huang et al., 2020; Riemer et al., 2020). Therefore, during early 2020, many IS designers and other stakeholders were faced with the sociotechnical design challenge of digitalizing contact tracing and designing CoTIS (Ferretti et al., 2020; Huang et al., 2020; Lin et al., 2021; Naous et al., 2022). Previous outbreaks such as Ebola and SARS followed a narrow tracing path (Anglemyer et al., 2020), and did not offer the practical knowledge required to navigate the complex interplay between CoTIS's technical features, the urgent need for its widespread deployment, and the unprecedented privacy, trust, and ethical dilemmas CoTIS introduced (Morley, et al., 2020). As such, although designers could rely on general technology knowledge and experience (Chandra Kruse et al., 2022) and high-level guidelines on health surveillance systems, in early 2020 there was a lack of domain-specific experience and design knowledge from other instances of CoTIS (Rowe et al. 2020).

The experience of CoTIS during COVID-19 also showed that designing IS to manage a pandemic-scale infectious disease is different from designing systems to detect relatively narrow outbreaks (Morley et al., 2020). Unlike other large-scale commercial IS or health IS (HIS), the design of IS to manage a VUCA situation can lead to unprecedented public scrutiny and fierce debates on civil liberties vs collective public health, adding to the complexity and ambiguity of designing the IS (Rowe et al., 2020). There might be urgency in the adoption and diffusion of the IS due to its socioeconomic value. During COVID-19, for instance, some countries linked the uptake of CoTIS to a relaxation of lockdowns and restrictions (Recker, 2021; Rowe et al., 2020). The VUCA nature of a pandemic can also compound the challenges of optimizing the "timeliness, sensitivity, and predictive value" (Hopkins, 2005) of the system. It also introduces new material considerations (such as a population's functional requirements and use cases) and social concerns (such as ethics, equity, fairness, privacy, and surveillance) that have not been the primary focus of prior surveillance systems research (Bravata et al., 2004; Hopkins, 2005; Hu et al., 2007). These differences can also be noted from civil society organizations' statements on the use of digital surveillance technologies[1] in early 2020 and the rapid research and commentary on how to 'do' CoTIS[2,3].

IS design research has provided valuable knowledge on creating IS artifacts (Maedche et al., 2021; Peffers et al., 2018). However, it lacks specific actionable knowledge to inform the design of IS in a VUCA situation. Most IS behavioral research has typically addressed relatively stable, clear, planned, and defined projects (Leonardi et al., 2016; Malaurent & Karanasios, 2020; Polykarpou et al., 2018; Rivard et al., 2011). Similarly, disease and bioterrorism surveillance research has focused on either description of the potential applications of such systems (Arani, 2021; Clements, 2009; Hopkins, 2005), outlining the technical specifications, ease of use, and usefulness of systems for sharing information among public health organizations (Hopkins, 2005; Hu et al., 2007) or evaluation of deployed systems (Shannon et al., 2023). Furthermore, CoTIS-related research primarily focused on behavioral aspects of end users' intentions (Goyal et al., 2021; Trang et al., 2020), resistance (Prakash & Das, 2022), and adoption (Abramova et al., 2022; Lin et al., 2021; Naous et al., 2022). Despite burgeoning CoTIS research, studies have for the most part yet to offer design knowledge that can be constructed from the deployment of CoTIS. Rowe et al's. (2020)'s lessons from a critical theory analysis of the French experience, Trang et al.'s (2020) ideal app specifications, and Recker's (2021) analysis of Germany's COVID-19 dashboard provide a few exceptions.. This leads us to pose the following research question:

RQ: How information systems to manage a VUCA health situation should be developed?

[1] https://www.amnesty.org/en/documents/pol30/2081/2020/en/

[2] https://contacttracingplaybook.resolvetosavelives.org/

[3] https://philpapers.org/rec/MOREGF

To address the research question, we conjecture that the experiences with CoTIS can offer opportunities to generate design knowledge. Therefore, we adopted the design research activity framework, particularly the "deployment" cluster (Maedche et al., 2021), combined with ideas from design archaeology approach (Chandra Kruse et al., 2019; Recker, 2021). Our process was systematic and iterative (Gregor & Hevner, 2013). We used the dimensions of design archaeology (Chandra Kruse et al., 2019) as a guide to retrospectively analyse the COVIDSafe artifact, the COVID-19 context in which it has been designed and used, the design process, and the views of different stakeholders.

Our analysis shows that the design of COVIDSafe was embedded with sociotechnical tensions related to what, why, how, and to whom to digitalize, and the gamut of trust, privacy, and civil liberty issues associated with those decisions. As we undertook the archaeological analysis, we also engaged in constant and iterative reflection to identify lessons from the COVID-19 context and COVIDSafe that could be abstracted to broader problems and solutions. We used literature on design theorizing (Gregor & Hevner, 2013; Lee et al., 2015), the anatomy of design principles (Gregor et al., 2020), and abductive reasoning (Baskerville et al., 2018) as a guide for our reflective/abstractive activities and to derive the basic components of an IDMIS design theory. Through this process, we contribute a nascent theory to inform future IDMIS designs and provide insights on how to manage sociotechnical tensions in the design of IS for managing VUCA health situations. Furthermore, by applying a design archaeology approach, we contribute a concrete example and normative reference for how IS researchers can observe real-world artifacts to generate design knowledge and add an instantiation of the approach to IS design research methodology.

The rest of the paper proceeds as follows. To establish the background of the phenomenon under study, we discuss the findings of studies on the management of VUCA and IS and on contact tracing information systems. We then outline our research approach. After presenting the findings of the design archaeology-driven analysis, we introduce IDMIS design theory, specifically its aim and key requirements, actors, application layers, and principles. We discuss the reusability of our design principles and conclude by highlighting our contributions, their limitations, and suggestions for further research.

2 Background Literature

Our literature review is in two domains. First, we review literature to establish the background of the phenomenon under study and the challenge of designing IS to manage a VUCA situation. Second, to highlight the unique contributions of the study vis-à-vis prior research, we review the CoTIS literature.

2.1 Management of VUCA with Information Systems

The VUCA concept describes four related challenges (Bennett & Lemoine, 2014). *Volatility* represents the unexpected nature of the challenge and the initial lack of knowledge about it. *Uncertainty* refers to insufficient information about the challenge. *Complexity* refers to a situation that involves many variables and *ambiguity* refers to unclear causes, solutions, and effects that require a high degree of experimentation. Research on VUCA has focused on developing strategies and solutions to manage VUCA situations, including the role of technology (Horney et al., 2010).

As part of a broader set of strategies, IDMIS can be useful in managing VUCA situations such as pandemics (Chen et al., 2011). They can help public health officials collect data about an infection, identify patterns and trends on how a virus spreads, and make informed decisions to respond quickly and effectively to changing circumstances (Ågerfalk et al., 2020; Ferretti et al., 2020; Huang et al., 2020).

Prior to COVID-19, either in response to disease outbreaks such as SARS, swine flu, and Ebola or in anticipation of bioterrorism attacks, researchers identified the need for surveillance systems. For instance, Hopkins (2005) described the purposes and technical parameters for developing infectious disease surveillance systems like dashboards. Their specification didn't consider the use of mobile apps that offer different sets of design choices related to the timelines, sensitivity, and predictive value of surveillance systems. Hu et al. (2007) developed and evaluated a web-based architecture for sharing and visualizing information to support the surveillance and detection of infectious disease by public health professionals. Their work focused on addressing technical challenges such as data and system integration, information visualization, and user acceptance testing. Other studies highlighted the importance of developing a surveillance system infrastructure as part of bioterrorism preparedness (Clements, 2009), or described the features and capabilities of IS for detecting bioterrorism outbreaks by integrating the latest technologies (Arani, 2021; Hao et al., 2022). While these studies have identified the potential and technical specifications of surveillance systems, they have also pointed out the limited availability, function, and effectiveness of such systems for clinical and public health decision-making (Bravata et al., 2004; Maddah et al., 2023). The studies have not produced IDMIS design knowledge.

During the early stages of the COVID-19 pandemic, there was great enthusiasm shown for the digital transformation of contract tracing and the use of CoTIS (Karanasios, 2022). Different countries developed or implemented either a centralized or decentralized CoTIS relying on Bluetooth or GPS technologies (Naous et al., 2022). For example, in Israel the government used mobile phone data to trace people suspected to be infected with COVID-19 (Riemer et al., 2020). South Korea and Taiwan's governments relied on patient data and travel histories (Riemer et al., 2020). Australia, Austria, France, India, and Singapore developed an app to trace user movement (Lin et al., 2021; Rowe, 2020). Germany, UK, Italy, and several US states adopted the Google-Apple Exposure Notification system (GAEN) (Naous et al., 2022).

All these examples demonstrate that designing IDMIS in a VUCA situation is a challenging task. Designers must adapt, experiment, and improvise quickly to create a feasible solution. They also need to consider the changing needs of stakeholders and communicate the system effectively to encourage rapid adoption by users. In the next section, we review prior works on CoTIS.

2.2 Prior Works on Contact Tracing Information Systems (CoTIS)

Broadly, the CoTIS literature falls into three categories: (i) critical analysis (Fahey & Hino, 2020; Rowe, 2020; Rowe et al., 2020); (ii) *ex ante* CoTIS user preference and governance suggestions (Riemer et al., 2020); and (iii) *ex post* behavioral studies on user acceptance, resistance, and use (Abramova et al., 2022; Goyal et al., 2021; Lin et al., 2021; Naous et al., 2022; Prakash & Das, 2022).

The critical analysis studies reveal several issues and risks associated with the introduction (Rowe, 2020; Rowe et al., 2020) and use (Fahey & Hino, 2020) of digital contact tracing. Some of the risks come from potential breaches when collecting contact or location data, unintentionally disclosing sensitive information about individuals in a harmful way (Fahey & Hino, 2020). Other risks include discrimination, distrust, and hidden ethical or moral dilemmas, as well as the possible normalization of surveillance (Rowe, 2020). These concerns contributed to the failure of the French CoTIS (Rowe et al., 2020).

Ex ante studies offered insights into user expectations of CoTIS, their potential appeal to different demographics, and how they can work effectively (Ågerfalk et al., 2020; Riemer et al., 2020; Trang et al., 2020). For instance, an experiment showed that when citizens are skeptical, governments should emphasize societal benefits and prioritize reducing privacy concerns (Trang et al., 2020). Another study indicated that, although privacy-preserving designs affect users' intention to install digital tracing systems, users were willing to trade privacy for other design features such as benefits to the self and society and convenience (Naous et al., 2022). Riemer et al. (2020) suggested strategies for CoTIS rollout and discussed the challenges of enforcing adoption and use.

Ex post behavioral studies applied pro-social behavior (Trang et al., 2020), trust (Lin et al., 2021), innovation resistance (Prakash & Das, 2022), consumption value (Goyal et al., 2021), and privacy (Abramova et al., 2022) theories. As a result, they modelled the research variables inconsistently and reported diverging results related to the effects of demographic, COVID-19, technology perception, privacy, trust, risk, and value appeal on user acceptance. Privacy concerns, for instance, had a negative effect on intention to install (Trang et al., 2020); no effect on user acceptance (Abramova et al., 2022); a negative association with trusting beliefs, which positively affected usage intentions (Lin et al., 2021); and a positive association with resistance and distrust in digital contact tracing (Prakash & Das, 2022). This indicates that behavioral studies haven't offered clear and consistent insights that designers can reliably use when developing future IS for the management and control of infectious diseases.

In summary, IS design in a VUCA situation presents unique challenges. It necessitates a design that is flexible, adaptable, and responsive to changing requirements. As noted, most prior CoTIS studies focused on digital contact tracing apps and the issue of data collection. They show individuals' adoption, acceptance, or diffusion of contact tracing apps in the context of increasing data collection. Stakeholders such as developers, contact tracers, and public health officials may hold different expectations and visions for CoTIS in managing the VUCA situation. The influence that their drivers, needs, and perspectives have had on CoTIS and the design knowledge that can be gained through observing CoTIS have not received sufficient attention. By adopting a design archaeology approach to generate design knowledge, we redress this oversight.

3 Research Approach

3.1 Observing Information Systems to Derive Design Knowledge

The effective design of IS remains an important but problematic area of IS research and practice (Chandra Kruse et al., 2022; Maedche et al., 2021). In the IS literature, design research and design science research (DSR) are used interchangeably (Iivari, 2007) with a focus on building theories (Gregor & Jones, 2007; Peffers et al., 2018) to guide practitioners' design processes. IS researchers also review design theories to try to improve them or generate new design theories (Baskerville et al., 2018; Venable et al., 2014).

Generally, DSR genres differ in "the problems that are addressed, the type of artifacts that are designed and evaluated, the research processes that are used …, and the type of knowledge contributions that are made" (Rai, 2017, p. iii). Maedche et al. (2021) provide a design research activity framework to distinguish four types of design research (Figure 1). Creating and evaluating an artifact (i.e., construction cluster in Figure 1) is a typical contribution expected from DSR (Peffers et al., 2018). However, as scholars (Maedche et al., 2021; March & Smith, 1995; Peffers et al., 2018) have indicated, construction-type DSR is not the only understanding or contribution. Knowledge contribution from DSR can take different forms and "a design instantiation is not obligatory to support a design theory" (Peffers et al., 2018, p. 131). Indeed, design knowledge can be prescriptive or descriptive, and may be contributed from either construction or observation of an artifact (Maedche et al., 2021). Figure 1 shows the four design activity clusters (Maedche et al., 2021) and positions our work within the "deployment" cluster.

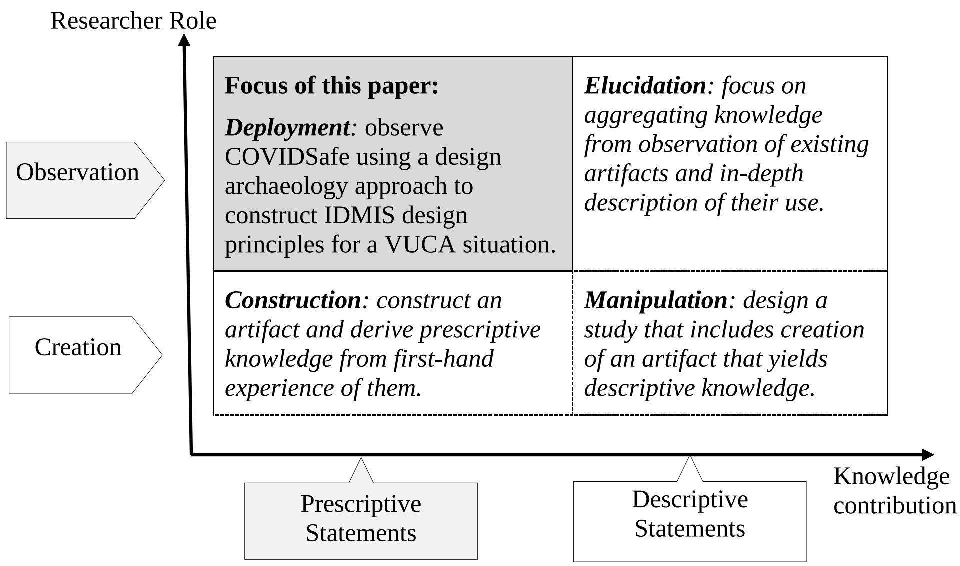

Figure 1. Positioning of the study based on Maedche et al. (2021)'s framework

Given our interest in "deployment" design research (Maedche et al., 2021), we undertook five activities: choosing the IS artifact for observation, defining the observation protocol, collecting evidence, analyzing the evidence, and design theorizing.

3.2 Choosing COVIDSafe for Observation

We chose Australia's COVIDSafe for observation, a CoTIS developed and launched on April 26, 2020, by the Australian Government Department of Health as part of the effort to fight COVID-19. We chose COVIDSafe for three reasons.

First, the system can be described as a partially successful system. Key stakeholders attained some of their major goals (such as industry-scale contact tracing capability and preserving privacy) without experiencing significant undesirable outcomes. However, like other CoTIS, its effectiveness and public health value has been questioned (Rowe, 2020; Vogt et al., 2022). Despite concerns, it received the highest score possible (five stars) on MIT's Technology Review Covid Tracing Tracker after its rollout (O'Neill et al., 2020). It also achieved rapid adoption, with over a million downloads in the first five hours and mass adoption evidenced by more than 7.7 million downloads. This constituted more than 40% of the adult population in Australia and at the time, the "third highest" (Lin et al., 2021, p. 392) uptake of a non-commercial CoTIS developed by a government. In late 2021, it was rated as 55th in the health and fitness category in Apple's app store with an overall four stars from more than 13,900 ratings.

Second, like other nations, its design, development, and implementation were surrounded by complex, fierce, and polarized technological, public health, and sociopolitical debates, providing an ideal context to learn about the requirements and design choices of IDMIS in a VUCA situation.

Third, the novelty of the innovation means there were several sociotechnical design tensions. The design of COVIDSafe was openly communicated and packaged, making it ideal for observation, retrospective analysis, and design knowledge generation.

3.3 Defining Observation Protocol

In order to observe the COVIDSafe artifact, we adopted a design archaeology approach (Chandra Kruse et al., 2019; Recker, 2021). Just as archaeologists make sense of the past, design archaeology aims to reconstruct how an IS artifact has been designed, implemented, and used in order to generate prescriptive design knowledge (Chandra Kruse et al., 2019; Recker, 2021). Design archaeology emphasizes artifactual analysis and people's interaction with artifacts. It can be used not only to explain historical design, design activity, and capabilities, but also to generate forward-looking prescriptive knowledge that can inform the future instantiation of a similar class of artifacts (Chandra Kruse et al., 2019) To do this requires a clear protocol defined in terms of analytical dimensions, unit of analysis, assumptions about the artifact, and the purpose of the knowledge produced (Chandra Kruse et al., 2019). **Error! Reference source not found.** presents the protocol we followed.

Table 1. Protocol for Design Archaeology Analysis

Area	Description (Chandra Kruse et al., 2019)	Our approach
Artifact of interest	Identify the artifact of interest	We chose Australia's COVIDSafe.
Assumptions about the artifact	Clarify "basic assumptions [static vs dynamic] about the nature of the artifact" (p.40)	Given the rapidly spreading and evolving virus, the design and development of COVIDSafe and its social context were fluid. Therefore, we assumed a dynamic object that changed across the design and use contexts.
Perspective	"Choose the relevant points of view, … how [stakeholders] conceive of an artifact-in-use, … what practices [they] envisioned … the artifact allowed for and why." (p. 40)	The unit of analysis was the design, development, and rollout of COVIDSafe, rather than its everyday use by citizens and health professionals. We took a holistic view and the perspective of three main groups: designers, users (citizens, contact tracers, and public health officials), and other stakeholders such as medical, IT and legal professionals, industry, opposition parties, and the media.
Analytical dimensions	"Consider the digital artifact in focus in terms of instrumental, historical, symbolic, and aesthetic dimensions to construct a holistic understanding." (p.40)	We focused on the artifact, stakeholders', historical, aesthetic, instrumental, and symbolic dimensions of analysis. Together, these analyses helped to identify sociotechnical requirements.
Knowledge production	Reconstruct knowledge and theory as a guideline for the future	We reflect on the results of the design archaeology analysis, embark on design theorizing, and generate an IDMIS design theory for a VUCA situation.

3.4 Evidence Collection

Design archaeology analysis relies on various sources of data (Chandra Kruse et al., 2019; Recker, 2021; Suchman et al., 2002). We collected different types of evidence to construct a substantial corpus. These included the COVIDSafe source code, screenshots of its workflow, its user interface and design, and descriptions of its operation and improvement. Our evidence also included public briefings, reports, and information from those responsible for the design and development of COVIDSafe, alongside media reports based on interviews with health, technology, privacy, and citizen advocacy groups and professionals. We also pieced together a sequence of events related to the COVID-19 and COVIDSafe context in Australia between January 2020 and August 2022. This multilayered approach was necessary because COVIDSafe crosses the boundaries of technology, health, ethics, and security, and the legislative and regulatory environment.

Instead of espousing a hypothesis or a theory, we entered the "site" with a neutral and exploratory approach informing our strategy for evidence collection, in line with design archaeology analysis. Between March 25 and April 26, 2020, we sensitized ourselves to the emerging context by undertaking a web search on terms related to COVID-19 mobile applications and system. This helped to reveal the key actors, stakeholders, and narratives. As the government committed to developing COVIDSafe, we shifted to a more targeted and purposeful sampling approach. This was essential for gathering the necessary evidence for our archaeological analysis (Rafaeli & Pratt, 2006; Suchman et al., 2002). We observed both the material and discursive design practices of COVIDSafe and developed an account of (i) how it was designed by examining the source code and other documentations to reveal how developers implemented the various layers of the COVIDSafe system, how they processed and stored data, how they integrated different components, and how they ensured the security and privacy of user data; (ii) how it worked by installing and using it; and (iii) how it was perceived by following the discourse post-launch.

All online content was examined by two of the researchers for relevance. First, we ensured that COVIDSafe was central to the theme of the article or website. Second, we ensured that the article/website provided some narrative regarding the design, development, implementation, and surrounding issues of COVIDSafe. **Error! Reference source not found.** summarizes the corpus of evidence extracted and analyzed.

Table 2. Summary of Corpus of Evidence

Source	Type of content	Number analyzed
GitHub	COVIDSafe app source code	1
Various artifact representations	System description, workflow, and UI screenshots	18
Digital Transformation Agency and Australian Government Department of Health	Release and update details (content, accessibility, performance, usability, privacy, security, functionality, software development environment, and source code)	26
Australian Government	Statements from the Australian Government Department of Health, Digital Transformation Agency, Department of Human Services, and other Australian Government departments.	17
Prime Minister's Office	Statements from the Prime Minister	7
Australian Medical Association	Media briefings and interview read outs	7
Online newspapers	News articles, opinion pieces, reports etc. The Australian (38), The Age (31), Herald Sun (18), The Daily Telegraph (10), The Courier Mail (20), The Advertiser (16), The Mercury (18), NT News (2), The Canberra Times (30), Online newspapers such as abc.net.au, sbs.com.au (20)	203
IT, cyber security	Reports, opinion, and interview readouts	16
Privacy experts	Reports, interview readouts	2
Academics and other opinion leaders	The Conversation articles, reports, opinions	8
Consumer groups	Reports and submissions	2
Total		307

3.5 Evidence Analysis Procedure

In analyzing the evidence, we adopted the iterative strategy used to study artifacts (Yanow, 2006) and technologies (Suchman et al., 2002), and the principles of digital ethnography (Cranefield et al., 2018). The analysis started with open coding of the corpus of data to familiarize ourselves with the evidence, develop a shared understanding of the phenomena, stakeholders, events, and perspectives and to work towards a heuristic, i.e., a set of guiding rules and norms to inform our subsequent analysis. We used NVivo software to create a database of articles, reports and government statements, memos written based on our review of the COVIDSafe app source code, and screenshots. Two of the authors undertook open coding, allowing codes to emerge with little attempt to identify overarching themes.

After frequent debriefings and negotiation, we settled on a code book and undertook two rounds of intercoder reliability testing to achieve a Kappa score of 0.96 (Appendix A). After this, two of the authors coded the data, frequently discussing their coding process, including the emergence of new codes, and ultimately producing 113 open codes (see Appendix B for the sample coding tree).

During selective coding, we transitioned to a more abductive analytical approach informed by the design archaeology analytical dimensions outlined in Table 1. We moved from many open codes to a more meaningful interpretation that aligned with our analytical focus. It enabled us to manage the volume of data and organize codes into a coherent structure. For instance, open codes that discussed the exploratory stages of COVIDSafe (e.g., system exploration, manual contact tracing, alternative solution) were aggregated to "historical dimensions", whereas those that both evoked a representation of COVIDSafe as a solution (e.g., "digital vaccine" and "social duty") as well as a destructive force (e.g., "fear of surveillance" and "privacy infringement") were aggregated to "symbolic dimensions". Through this analysis (Figure 2 and Appendices C-G), we developed the historical, artifactual, stakeholder, aesthetic, instrumental, and symbolic findings.

3.6 Design Theorizing Procedure

We used the anatomy of design principles (Gregor et al., 2020) as a high-level blueprint and applied the research teams' reflective judgement and causal reasoning (Baskerville et al., 2018; Gregor & Hevner, 2013; Lee et al., 2015) on the construction process and performance of COVIDSafe to derive the basic components of an IDMIS design theory and move from analysing the instance problem and solution to defining the abstract problem and solution. Two key questions guided this process: (a) what sociotechnical lessons can be extracted from the analysis of COVIDSafe; and (b) what the implications of those lessons are to guide future design of sociotechnical information.

As an example of this approach, we generalized the problem of the COVID-19 pandemic into the broader problem domain of managing infectious diseases in a VUCA public health situation. While COVIDSafe can be considered as an instance of CoTIS, our reflection went further to abduct the more abstract solution domain of IDMIS. The reflection on the stakeholder and historical design archaeology analysis findings helped us to focus on COVIDSafe's idea generation and design decisions. This led us to abstract the key actors in the IDMIS, and the aim and scope of the future design efforts for which the design principles could be useful. Through reflection on the artifactual, instrumental, and aesthetic dimensions, we were able to abstract and analytically divide the IDMIS application into four layers. By engaging in the process of "active and passive causal analysis" (Gregor & Hevner, 2013, p. 7), we then identified building blocks for our design principles. During this process, we went back to the more granular findings from our archaeological dimensions in order to prescribe mechanisms for each design principle (see Appendix J for a complete mapping).

Through this iterative process, we identified five components of an IDMIS design theory (Figure 2 and Figure 4): (i) IDMIS aim and requirements; (ii) actors; (iii) context; (iv) mechanisms; and (v) IDMIS application layers.

To communicate our design theory, we followed Gregor et al.'s (2020) template and positioned the design principles in terms of applicability in a new context. We chose Gregor et al.'s (2020) template for its ease of use and usefulness in formulating design principles but recognise that other researchers may prefer other forms (such as text narrative) to communicate the same knowledge. Figure 2 captures the analytical and design theorizing process. However, we acknowledge the process was more dynamic in practice as we cycled back and forth between design theorizing, design archaeology, and the data.

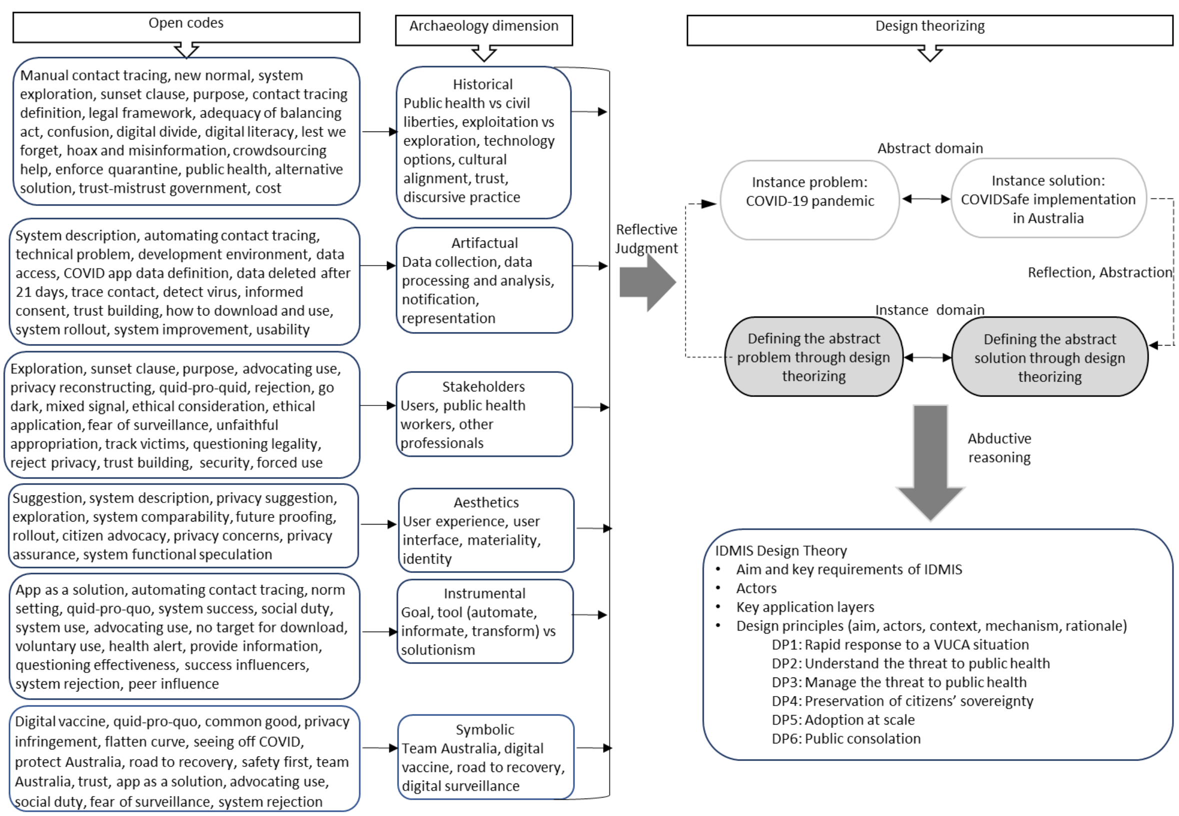

Figure 2. Evidence analysis and design theorizing process

4 Findings

In this section we discuss the historical, artifactual, stakeholders, aesthetic, instrumental, and symbolic dimensions of COVIDSafe. These findings help to construct generalizable principles for designing IDMIS in a VUCA situation.

4.1 Historical Dimension

The COVID-19 outbreak spread to different parts of the world very rapidly. Australia had its first confirmed case on January 25, 2020. Initial measures to control the virus included closing off international borders to non-residents, declaring the virus a human biosecurity emergency, banning non-essential indoor and outdoor events, introducing social distancing and strict lockdowns, as well as manual and interview-based contact tracing. The early experience of countries such as Singapore and South Korea that appeared to control the spread of COVID-19 suggested effectiveness of digital tracing in managing COVID-19. Figure 3 provides an overview of COVIDSafe related events and timelines.

In Western democracies, one of the fundamental public health debates is the relationship between a government's power to implement measures and the erosion of civil liberties (Huang et al., 2020; Rowe, 2020; Rowe et al., 2020). In the fight against infectious diseases there is an enduring tension between the extent a government can force the implementation of solutions in the interest of public health, and the acceptability of such measures in terms of individual rights (Recker, 2021; Rowe, 2020; Rowe et al., 2020). This dilemma resurfaced in Australia's consideration of digital contact tracing. Designers also faced the challenge of determining the boundaries of what to digitalize, as the line between contact tracing within the community and monitoring individuals' movements to prevent them from breaching quarantine and spreading COVID-19 was unclear.

When deciding to digitalize contact tracing, Australia had two options: to adopt an exploratory approach and develop an indigenous solution or to adopt an exploitative approach and use solutions employed and tested by other countries. Balancing the two approaches created tensions in planning, design, and delivery.

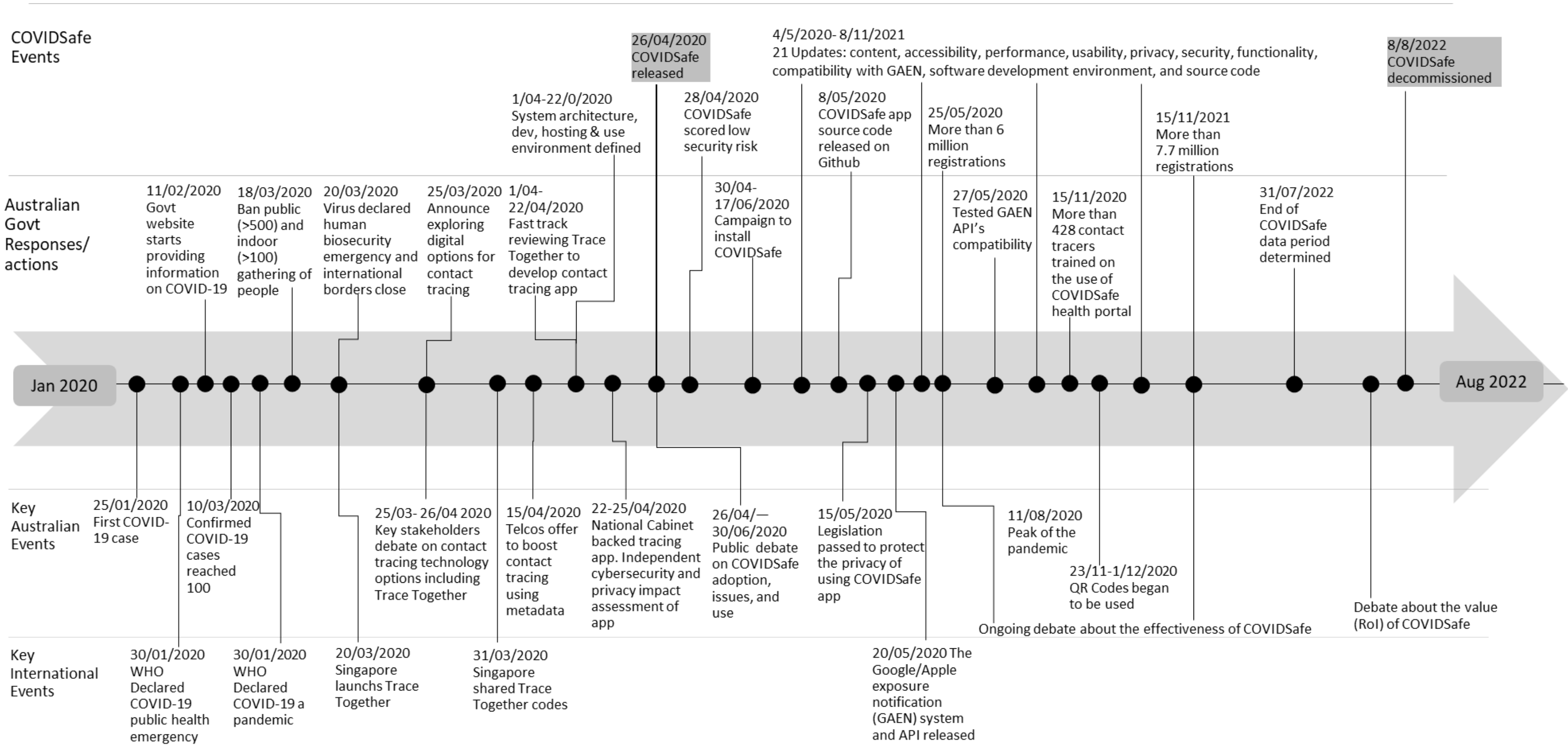

Figure 3. COVIDSafe Timeline

Despite suggestions to use either the metadata from Australia's top telecommunication companies or the Apple-Google technology being developed at the time, the Australian Government followed an exploitation strategy and adapted Singapore's TraceTogether contact-tracing solution. On April 14, 2020, the government announced the development of a contact tracing app, COVIDSafe, to achieve "industrial capability" for contact tracing. The app was presented as one of the three requirements before social restrictions could be lifted (Appendix C). The project was handed to the Digital Transformation Agency with backing from the prime minister, the attorney general, the chief medical advisor, and cybersecurity experts. The government's chief medical officer viewed the "better use of technology … as critical to getting on top of the virus, … ease lockdowns … and consider some relaxation of (social distancing) measures" [The Australian, April 15, 2020].

The government's choices of TraceTogether and Bluetooth were not without criticism, due to the ideological and cultural differences between Australia and Singapore. The Digital Transformation Agency had to strip down some of the functionalities of TraceTogether to make sure the solution aligned with Australian values. To build public trust and confidence, it made the source code available for selected stakeholders during development, and widely available following public rollout. These planning and governance choices highlight the tension between need for rapid development and release and wider public oversight of a stable solution, resulting in mixed reactions.

The government released the COVIDSafe app on April 26, 2020, for installation on iPhones and Android smartphones with at least iOS 10 and Android 6.0 operating systems, respectively. This delivery choice was criticized for "preventing hundreds of thousands of Australians from using COVIDSafe" [The Advertiser, May 6]. To encourage mass acceptance, a communications campaign was launched on April 30 consisting of a series of videos, radio, and social media explaining the app and encouraging citizens to download and use it (Australian Government, 2021a). A dedicated website was created for user support. The website provided background information, help topics, a privacy policy, access to the source code, and a user guide, initially in English, which was eventually translated into 63 languages (Australian Government, 2021a). Legislation was enacted to govern COVIDSafe's data use (Appendix C).

To build trust, association and social embodiment strategies were used, drawing on the testimonial of notable Australians, as well as IT, legal, health, and medical professionals:

> *"Anything that helps us wrestle COVID-19 to the ground is a plus. Any privacy any of us had pretty much disappeared when we started using mobile phones, searching online, buying stuff from Amazon or whatever,"* [Australian Nobel Laureate and Immunologist]

For some, the authority of these professionals held more weight in terms of sense-making and trust than politicians' assurances. Despite significant investment in communication campaigns though, inconsistent and unclear discursive practices occurred. Government officials and other stakeholders that conflated contact tracing (i.e., the process of identifying and notifying individuals who have been in close contact with someone infected with COVID-19) with contact tracking (i.e., tracking the movement and interactions of individuals within a community or population). This led to confusion, concerns, and reservations around the installation of COVIDSafe. Between its release and decommissioning, the app was updated 21 times.

4.2 The COVIDSafe Digital Artifact

COVIDSafe was a sociotechnical system composed of four key components: (a) the COVIDSafe app for Android and iOS mobile devices to collect data from users and notify them of critical information; (b) a National Data Store where information collected or generated using the COVIDSafe app was processed and stored securely; (c) a server Application Program Interface (API) for managing registrations, issuing identifiers, and receiving uploaded exposure information from the mobile apps; and (d) a web portal that authorized Australian state and territory public health authorities to access the uploaded exposure information and monitor the spread of COVID-19 (See Appendix C for a sample of COVIDSafe data flow, process, and user interfaces). Since detailed descriptions of COVIDSafe can be found in Lin et al. (2021), Vogt et al. (2022), and Australian Government (2021a, 2021b), we provide only a brief account of it here.

According to the source code and other documentation/description available, COVIDSafe was developed using a range of tools and development frameworks. The app was built using the React Native framework, which is a popular cross-platform development tool for building mobile apps. The app's backend was built using Amazon Web Services, which provides a range of cloud-based services including Amazon API Gateway and Amazon Simple Notification Service (SNS), for building and running applications. The COVIDSafe app used Bluetooth for proximity detection and communication between devices. In June 2021, it was updated to be compatible with the Google and Apple Exposure Notification (GAEN) framework for contact tracing.

Architecturally, COVIDSafe was designed to handle four main tasks: data collection, processing, representation, and notification.

Data collection: Data were collected using the COVIDSafe app. To collect data, users needed to download the app and register by providing their phone number, postcode, age range, and names (or pseudonym), as depicted in Appendix C. When two or more individuals running the COVIDSafe app came into close spatial proximity, a digital handshake was established and users' temporary IDs, the phone model information, Bluetooth signal strength, date and time, and proximity of the contact were exchanged and recorded securely on the users' devices. User locations were not recorded. The contact information was stored on users' devices for 21 days.

Data processing and analysis: The COVIDSafe app was a thin client to harvest contact data and transmit it for processing in the backend. Some of the processing included anonymizing users by generating and cycling through temporary and unique mobile device identifiers and encrypting the registration information using AES 256 military-grade encryption. The data were stored on a server in Australia for processing, and it was a criminal offence to hold the data on a database outside of Australia (Appendix C). However, how to manage the data volume from COVIDSafe's database and portal did not receive much attention. Although big data analytics and AI technologies can facilitate contact tracing, to the best of our knowledge, the Digital Transformation Agency had not implemented advanced and dynamic data mining and machine-learning techniques to effectively assist the operational decision of contact tracers who were overwhelmed by data volume. Thus, public health staff reported that "the process of ascertaining which of the app-suggested contacts who were not already identified through the case interview were close contacts could be lengthy" (Vogt et al., 2022, p. 254). This shortcoming could have been addressed with the use of data mining and machine-learning techniques, an insight we draw from in our design theorizing.

Notification: COVIDSafe used push notifications. Some notifications were generated by the app itself, while others were initiated from the backend (Appendix C). If a user came into close contact with someone who had tested positive for COVID-19, they received an alert and were requested by a health official to voluntarily upload the data stored on their mobile device to the secure national server. Users had the option of not sharing their COVIDSafe app data with the national server and permanently deleting it from their device.

> *"If you delete the app, this will delete all app information from your phone. The information in the storage system will not be deleted until the end of the pandemic, however if you would like it to be deleted sooner, you can request this online through a data deletion form."*

Representation: the COVIDSafe system used the COVIDSafe app with a simple layout to interface with end users. By contrast, contact tracers and public health officers used the COVIDSafe portal. The COVIDSafe portal provided a dashboard that displayed real-time COVID-19 case data, including the number of confirmed cases, recoveries, and deaths. The data were represented in graphs and charts for public health officials and policymakers to monitor the situation and make informed decisions. During design and improvisation of COVIDSafe, much attention had been on the efficacy of Bluetooth technology, privacy concerns, accessibility, and how to achieve mass acceptance of the app; less attention was given to representing the requirements of public health staff. For instance, a qualitative study found that COVIDSafe

> *"…was perceived as considerably less useful than public health staff had hoped. Its interface was not considered to be user-friendly and, especially early in the roll-out, staff at public health units required substantial assistance to access and interpret the data, resulting in inefficiencies and delay."* (Vogt et al., 2022, p. 254)

4.3 Stakeholders' Dimension

In order to reconstruct the sociopolitical context and requirements of an artifact, one must start by choosing "the relevant points of view, assumptions, and components" (Chandra Kruse et al., 2019, p. 40). Given our sociotechnical approach, we focused on the perspectives of designers, users, and other stakeholders. The Australian Government, including the Australian Government's Digital Transformation Agency, the Department of Health, and the Attorney-General's Department were the designers of COVIDSafe.

There were three main user groups (actors): (i) individual users of the COVIDSafe app; (ii) public health workers and contact tracers who used the contact information for tracing COVID-19 exposure; and (iii) health and government officials who were attempting to understand how the virus spreads and then devise policy. Other stakeholders were medical, IT, and legal professionals, industry, trade unions, opposition parties, and the media. Our findings identify how the designers, users, and other stakeholders "conceived" of COVIDSafe and what "practices" they "envisioned" and what it "allowed" (Chandra Kruse et al., 2019).

As designers of COVIDSafe, the Australian Government's Digital Transformation Agency and the Department of Health envisioned an industry-scale COVID-19 contact tracing capability (Appendix D). Early on, the Australian Government recognized privacy and trust to be critical issues for the mass adoption that it was aiming for: "There are a lot of issues that we still have to resolve for its use in Australia and the privacy issues are paramount amongst that." (Prime Minster Scott Morrison, The Courier, April 19, 2020)

As a result, it implemented a range of measures including the Biosecurity Determination Act to govern the use of COVIDSafe. In the context of tough social distancing and lockdown measures, the designers expected the use of COVIDSafe to be a "smaller step", something that citizens could install and "always keep open" (Appendix D). Designers also expected that it would afford them the means to ease lockdown and return Australia's social and economic life back to normal. These steps didn't stop the emergence of a digital surveillance metaphor, indicating the ideologically contested nature of privacy and the role of government.

Because technology-in-design is different from technology-in-use or technology-in-practice, (Orlikowski, 1992)different users can interpret, appropriate, and use the same information system differently. Individual users and stakeholders of COVIDSafe envisioned a range of possibilities. Some were altruistic about its use, seeing it as a solution to either "*stop … from dying … or helping … public health officials*" (Appendix D), and believed that using COVIDSafe was a social duty and a personal contribution to protecting Australia, a cause worth the sacrifice of privacy. Others were egoistical and bought into the *quid pro quo* framing presented by the designers that if they used COVIDSafe, the virus wouldn't spread, lockdowns would get lifted, and life would return to normal. Yet others manifested liberal views about privacy, mistrusted the government's intentions, and saw the app as a "surveillance" tool.

Health and medical professionals, who expected to use the contact data to trace and understand the epidemiology of the virus, believed (at least initially) that COVIDSafe would speed up their work by augmenting rather than replacing interview-based contact tracing (Appendix D).

> *"As an epidemiologist, I think anything that speeds up contact tracing is incredibly helpful for shutting down the spread of such a highly contagious virus as COVID-19."* [Epidemiologist]

> *"Without this technology, health officials have to rely on people being able to remember who they have been around and being able to provide contact details for those people."* [Chief Medical Officer]

This was a reasonable expectation as it was believed that a digital system would be quicker than manual contact tracing. While they showed enthusiasm for the use of COVIDSafe, these professionals also emphasized that privacy, technical, and practical issues needed to be appropriately addressed (Appendix D).

> *"The app simply automates a significant component of the current manual process of tracing who has come into contact with COVID-19…Privacy, technical, and practical issues must be assured, and the inevitable challenges in the app's rollout need to be anticipated and prevented."* [Australia Medical Association president]

Beyond these primary actors, there were stakeholder groups that represented distinct interests and expected different benefits. The various stakeholders drew on their "attitudinal orientation, political cynicism, and philosophical preferences and convictions" (Rowley, 2011, p. 57) to influence design specifications and choices, the framing of the technology, and the resistance to and willingness to use the system. In the design and development of the system, stakeholders urged designers to ensure that legislation included a sunset provision to protect privacy. For example, a group of data privacy professionals and academics published recommendations for legislation to make COVIDSafe trustworthy. Other stakeholders, such as legal and technical professions (e.g., programmers/software engineers, security specialists), saw COVIDSafe as a solution to the pandemic. However, they also expressed concerns about the security and privacy of the collected data, offering legal suggestions, technical advice, and assessment of the publicly available source code (Appendix D).

4.4 Aesthetic Dimension

The aesthetic dimension refers to the "experience (both formal and sensory) when encountering and using" a digital artifact (Chandra Kruse et al., 2019, p. 40) and encourages examination of COVIDSafe's material knowledge. As COVIDSafe did not have an Australian precursor and was based on Singaporean technology, users and stakeholders initially imagined it to stimulate sense-making, enthusiasm, and cynicism. When it was instantiated, it stimulated emotions reflected in debates, statements, and articles about the appropriateness of Bluetooth technology, the source code, the choice of Amazon Web Services, security, privacy, trust, civil liberties, and the role of government (Appendices D & E). Materially, instead of the décor (clean white layout, black text, minimal green images, and buttons), the ideology of health and other sociotechnical requirements such as the

Bluetooth performance, availability of COVIDSafe on older phones, and interoperability with Android led to displeasure, a senate enquiry, and 21 updates (Appendix D & E).

COVIDSafe also evoked "aesthetic feelings" (Rafaeli & Pratt, 2006, p. 26) and acquired several identities as a "tracing tool", "tracking tool", "ticket", "vaccine" and "game changer". These show the complexity of the reasons for digitalizing contract tracing and tensions around privacy, trust, and value.

4.5 Instrumental Dimension

The instrumental dimension analysis involves evaluating the "extent to which the artifact contributes to performance or to promoting goals" (Chandra Kruse et al., 2019, p 38). As indicated in Appendices D and F, there was confusion, contradictions, and inflated and unrealistic expectations of COVIDSafe and its public health value. COVIDSafe was associated with different perceptions such as "tracking down anyone" and "tracking movements" on the one hand, "suppressing the virus", "alerting Australians", "containing further transmission", "saving lives" on the other, or being a "game changer" and a "ticket to opening up the economy" (Appendices D and F). The government as the developer along with other stakeholders had different expectations of *why* to digitalize contact tracing. These coalesced as two dominant views: COVIDSafe as a tool vs COVIDSafe as a solution.

As a tool, COVIDSafe was expected to ameliorate the unreliability of human recall. Automation was expected to substitute labor for contact data collection and enhance the efficiency and reliability of both contact tracing and information processing. It was also expected to inform (Zuboff, 1988) health officials upstream with epidemiological data to protect public health, and downstream, to protect citizens from the risk of coming into contact with the virus.

As in other countries (Recker, 2021; Rowe, 2020; Rowe et al., 2020), there was an extreme and dominant 'digital first' solutionism belief instead of 'digital also' from both the Australian Government and proponents of COVIDSafe. Despite reasonable consultations that involved several key stakeholders that should have mitigated this belief, the Australian Government and other stakeholders used metaphors such as "digital vaccine," "sunscreen," and "road to recovery," suggesting that COVIDSafe could protect individuals from being infected and return life back to "normal". This, in the parlance of Rowe (2020, p. 4) shows "pure technological solutionism that runs completely against all sociotechnical lessons from IS and other sociotechnical disciplines". It also goes against the core principle of IS design science research, which proscribes precise definition of a solution's objective and specification of the purpose and scope of the IS artifact (Gregor & Jones, 2007).

Overall, our evidence (Appendices C, D, E, F, H) suggests that COVIDSafe was a "partially successful" (Heeks, 2006) system, as indicated in Table 3.

Table 3. Subjective evaluation of COVIDSafe's performance

COVIDSafe goal	Goal achievement	Evaluation justification
Automating manual contact tracing	*Fully met*	From the designer's perspective, one of the primary goals of COVIDSafe was to automate manual contact tracing. This goal was achieved, although its ultimate value and effectiveness have been questioned, due to poor performance when running in background mode (Vogt et al., 2022) and the continued effectiveness of manual contact tracing processes.
Develop industrial-scale tracing capability	*Fully met*	The Australian Government has created sociotechnical capability, organizational learning, and absorptive capacity for developing contact tracing systems.
Mass adoption and diffusion	*Met*	While 40% adoption was expected (Meixner, 2020), the diffusion rate of COVIDSafe has been greater than 40% (Australian Government, 2021a).
Improving the efficiency and accuracy of contact tracing	*Partially met*	As of 15 May 2021, a total of 1.65 million digital handshakes were uploaded to the National COVIDSafe Data Store (Australian Government, 2021a, 2021b). The COVIDSafe system has identified 2,827 potential close contacts from more than 37,688 encounters. COVIDSafe data led to the identification of a relatively small number of contacts. This can be partly attributed to the success of Australia's suppression strategy. But empirical evaluation suggests that COVIDSafe was "an additional step that increased workload without delivering any added value" (Vogt et al., 2022, p. 255). Furthermore, Australian states had also introduced QR code scanning at public places (such as transport, shops, sport venues, cafes, hotels, and restaurants).
Easing restrictions, opening the economy, and returning to normal	*Not met*	Despite initial expectations, Australia continued to impose tough restrictions and remained in lockdown until late 2021.

Suppressing COVID-19 and its spread	*Not met*	A contact tracing app doesn't offer either dispositional or emergent affordances to suppress the spread of a pathogenic virus whose epidemiological characteristics evolve over time.

4.6 Symbolic Dimension

The symbolic dimension analysis of an artifact looks at "the meanings or associations that are elicited when interacting with the artifact" (Chandra Kruse et al., 2019, p. 44). COVIDSafe is an important Australian digital artifact that held different meanings for politicians on either side of government, regulators, citizens, health professionals, and other stakeholders. Our findings revealed that stakeholders associated COVIDSafe with four overlapping metaphors: "Team Australia," "Digital Vaccine," "Road to Recovery," and "Digital Surveillance" (Appendix G). These metaphors show the tensions in the VUCA, public health, and sociopolitical requirements when designing and deploying an IDMIS.

Australian culture has a strong sense of "mateship", with a deep appreciation of "Aussie battlers", individuals who persevere through adversity (Austin & Fozdar, 2017). When the population faced adversity during COVID-19, proponents of COVIDSafe evoked the patriotic symbol of "Team Australia" to rally all members of society to "play their part" and install and use COVIDSafe as a "Team Australia moment" (Appendix G).

Espousing a technological solutionism perspective, some viewed COVIDSafe as a complete solution to the pandemic. Eventually, analogies were made between COVIDSafe as a digital solution and vaccines as a health solution. COVIDSafe was labelled a "digital vaccine" and contact tracing data became "virtual antibodies". In parallel to the patriotic and vaccine symbolism, COVIDSafe was also seen as a solution to the negative impacts of lockdown on the economy. Many individuals and businesses advocated for the use of COVIDSafe as they believed it to be a key part of the "road to (economic) recovery". In contrast to these pro-COVIDSafe metaphors, others rejected the system as government overreach and viewed it with mistrust. The government set out to assure the public that COVIDSafe was voluntary, that it would not track users' locations, and set up a legal framework for its use. However, anti-government sentiments persisted around impingement of liberties, erosion of democracy, and fears of autocracy. Some opinion leaders adopted an Orwellian metaphor, suggesting COVIDSafe was a step toward state surveillance, a digital panopticon.

4.7 Summary

Analysis of the historical, artifactual, stakeholder, aesthetic, instrumental, and symbolic dimensions show that the design and roll out of COVIDSafe was embedded with both imaginative and experienced tensions around what to digitalize, why to digitalize and, how to digitalize a CoTIS to manage an infectious disease. Because COVIDSafe was instantiated in a VUCA context, the analysis highlights both global and Australia-specific sociopolitical issues that emerge from those decisions. These findings enable "contemplation of the designer's perception of the design situation and of the remembered design activities" (Reymen 2001 in Gregor and Hevner 2013, p. 5). They also suggest that an IDMIS needs to balance three broad requirements that we label as VUCA, infectious disease, and sociopolitical. (i) VUCA: IDMIS must be designed to navigate and operate in unpredictable and complex scenarios; (ii) infectious disease: IDMIS should address the considerations of public health, ensuring community safety and wellbeing; and (iii) sociopolitical: IDMIS must balance delicate societal and political perspectives to avoid tensions". Based on these findings, in the next section we discuss an IDMIS design theory derived from our archaeological analysis of COVIDSafe.

5 Design Theorizing from an Archaeological Analysis

The case for IS to augment COVID-19 contact tracing efforts depended on resolving the tension among the VUCA, infectious disease, and sociopolitical requirements. While similar issues around digital artifacts, systems, and structures arose with other HIS initiatives, they were particularly prominent with COVIDSafe. Alternative perspectives on privacy in relation to civil liberties and the role of the state in a democratized society came to the fore. Designers needed to navigate these tensions while addressing a critical health problem.

We reflect on the results of our analysis to embark on design theorizing. We proceed by mapping the evidence to the components of the anatomy of design principles (Appendix J) and generalizing the insights from COVIDSafe in Australia to other comparable design contexts. Figure 4 shows how we moved from analysis of COVIDSafe for the COVID-19 pandemic to advancing design knowledge of IDMIS to address a VUCA health situation.

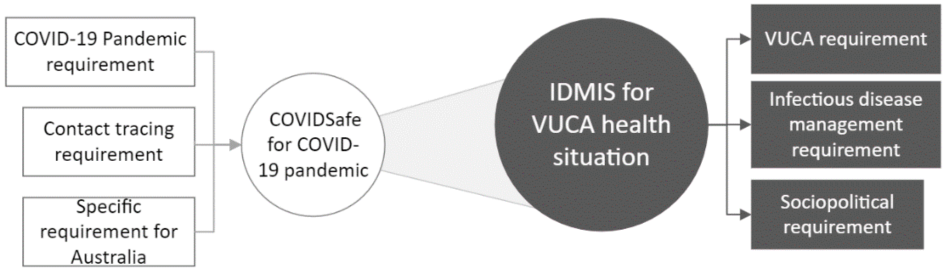

Figure 4. Generalizing insights from COVIDSafe to future design of IDMIS

We view the COVID-19 pandemic as an instance of a VUCA public health situation. This abstract problem (cf. meta-requirement (Walls et al., 1992)) can be addressed with an IDMIS and an abstract solution (cf. meta-design (Walls et al., 1992)) that CoTIS would be part of. Each problem-solution pair has three requirements for the design: VUCA, infectious disease management, and sociopolitical. Figure 5 provides an overview of our design theorizing.

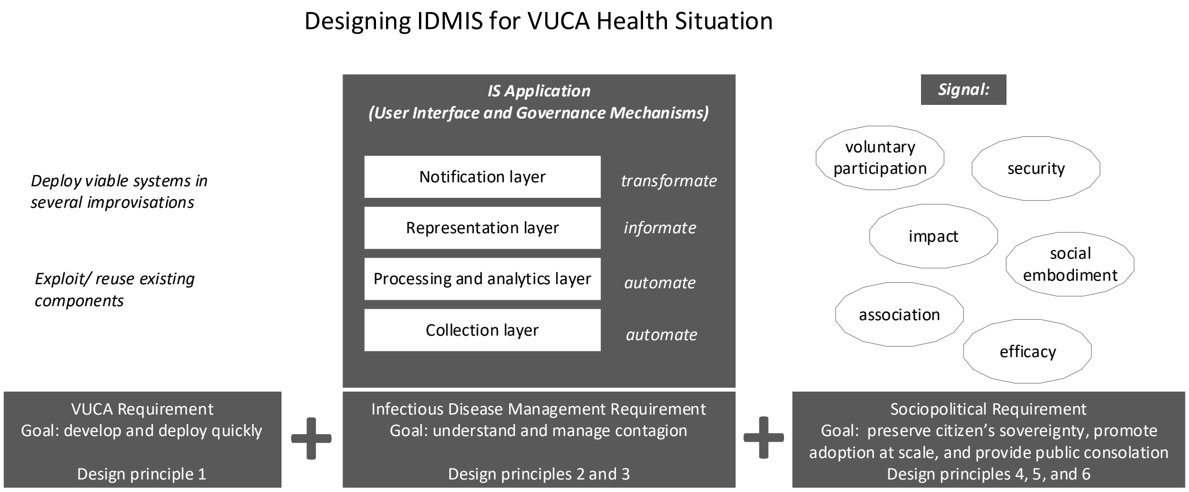

Figure 5. Designing IDMIS for VUCA health situation

In the next section we elaborate our design theorizing on IDMIS for VUCA situations. We discuss the following: its overall aim and key requirements; actors; key layers of the IS application; design principles; and design principles reusability.

5.1 Overall Aim and Key Requirements of the IDMIS

The overall aim of our design theorizing is to understand how to design a public IDMIS, as a sociotechnical system, for a VUCA situation. The goal of this system is to support its users (individual users, healthcare workers, and public and government officers) to understand and manage infectious disease threats to public health and, more importantly, to respond to the situation as quickly as possible while still adhering to country-specific conditions.

Accordingly, the design of a public IDMIS for VUCA situations should consider three key requirements: VUCA, infectious disease management, and sociopolitical. The VUCA requirement refers to the need for quick action in response to a specific VUCA situation. The infectious disease management requirement makes up the core functional requirement; that is, the ability to support the different user groups (e.g., citizens, health workers, and public health policy makers) in understanding and managing threats to public health (e.g., contagion). Our design theorizing setting is embedded in a democratic sociopolitical system (i.e., Australia). The sociopolitical requirement reflects this system and comprises the need for preserving citizen sovereignty and conforming with citizen demands for privacy and transparency, while also promoting voluntary and wide participation.

5.2 Actors

Following Gregor et al. (2020), we identify citizens and healthcare workers as recipient users of the IDMIS and public health and government officers as its enactors. Citizens provide information for the IDMIS and, in turn, receive processed information, advice, and recommendations. Healthcare workers also receive processed information relating to infectious disease management requirements to inform their decision-making. On the other hand, public health and government officers enact some mechanisms to achieve goals, especially those related to the VUCA and sociopolitical requirements. Implementors of the design principles (i.e., designers of IDMIS) may vary across VUCA situations, from an ad hoc working group to a dedicated national institution.

5.3 Key IS Application Layers

We view the IDMIS application as the main design unit (Iivari, 2017), while still acknowledging it as a sociotechnical system. In addition to the user interface and system governance layers, we analytically divide the IDMIS into four different design layers: data collection, data processing and analytics, representation, and notification. The logic of each layer is inspired by the automate, informate, and transform roles of information systems (Cash et al., 1994; Zuboff, 1988). According to Cash et al (1994), "when an information technology substitutes for human effort, it automates a task or process. When information technology augments human effort, it informates a task or process. When information technology restructures, it transforms a set of tasks or processes" (p.v).

The data collection layer: an IDMIS requires design of data collection mechanism to gain epidemiological information from citizens, hospitals, and other sources that will be used to understand potential exposure and contact with infection. Computational epidemiology defines a contact as either a direct or proximity interaction (Chen et al., 2018). While direct interaction implies physical contact between individuals (such as a handshake), proximity implies indirect interaction based on spatial closeness, such as being in the same room or using public transport. In designing the data collection layer, designers need to consider the specific epidemiology of the infectious disease (i.e., whether it is transmitted through direct or indirect contact) and the privacy implications of tracing (such as Bluetooth) and tracking and tracing (such as GPS) data collection technologies. In addition to assuaging privacy concerns, building trust, and facilitating acceptance, designers should implement an appropriate regulatory or legal instrument, including a sunset clause, to govern the use of the data collected.

The data processing and analytic layer: An IDMIS requires design of a flexible and scalable ICT infrastructure with properly governed service levels, cybersecurity, and applicable data protection arrangements such as geolocation of servers vis-à-vis national data protection regimes. To effectively assist the operational decision-making of the different actors and the management and control of infectious disease, advanced and dynamic data mining, analytics, machine learning techniques, statistical analysis tools, and visualization tools should also be included. To connect the system to different data sources and systems, such as electronic health record and public health surveillance, it should include features for API integration and data streaming. These choices should consider the need for a responsive digital solution, the urgency of infectious disease, and the interest in relatively rapid development and release.

The representation layer: An IDMIS is expected to inform health officials upstream with epidemiological data to protect public health, and downstream, to protect citizens from the risk of contracting the virus. The representation layer should allow affordances for automating all the infectious virus management activities and processes, and for presenting data and information to users in a meaningful way. The design of dashboards, graphs, charts, and reports should allow public health and government officers to understand the state, and pattern of transmission of the infectious disease, and to devise appropriate controlling mechanisms. Different users should also be given customization options, such as the ability to select different display formats or adjust the level of detail shown.

The notification layer: IDMIS should include both push and pull alerts and notifications. These should be directed to public health officials, healthcare providers, and the general public to inform them of key events or changes in the system, cases and status of infectious diseases, and risk of exposure. The design of the notification layer should consider appropriate discursive design considerations and use of symbols and culturally appropriate symbolism to convey important information quickly and clearly and to manage effectively public anxiety about the disease. It may also include features for automatically generating and distributing outbreak reports, risk assessments, and other public health advisories. Furthermore, the design should include features such as language selection and sound or vibration alerts to cater to the needs of different end user communities and provide them with different notification options.

In addition to the above, the IDMIS should include an easy-to-use user interface that allows diverse users to interact with the system. It should also include governance for implementing the business logic of the system, such as rules for data validation, processing, and storage, and for handling user authentication, access control, and security.

5.4 Design Principles

In order to address the VUCA, sociopolitical, and infectious disease management requirements of the IDMIS, we prescribe (Table 4) not only "what to design" (Design Principle (DP) 3 and DP4), but also "how to design" (DP1) and "how to deploy the design" (DP5 and DP6). The design principles formulation follows the structure proposed by Gregor et al. (2020).

5.5 Positioning our Design Principles

The ultimate goal of our design theorizing is a set of principles that are applicable for or reusable by future designers of IDMIS in their unique design contexts (Chandra Kruse et al. 2022). We also acknowledge the idea of design theory indeterminacy; that is, "the absence of a one-to-one mapping from design theory prescriptions to specific features in an artifact and methods for deploying the artifact in the environment" (Lukyanenko & Parsons, 2020, p. 3). The design principles are tentative. They should be subject to repeated testing and, if required, revision or even refutation. According to (Iivari et al., 2021), the reusability of a set of design principles can be guided by the following criteria: accessibility, importance, novelty and insightfulness, actability and guidance, and effectiveness.

We aimed for accessibility and actability by formulating our design principles according to a commonly used template in IS design research (cf., Gregor et al. (2020)). Moreover, designing IDMIS for VUCA situations is an important and relevant effort in today's IS design discourse. Our design principles are novel and insightful because there is no prior work that offers comparable prescriptive design knowledge. Finally, our design theorizing draws on our analysis of implemented and adopted IS (i.e., COVIDSafe). In so doing, we learn from its successes and failures in different aspects—design, implementation, and use. The design principles reflect this learning and prescribe how to design a successful IDMIS in VUCA health situations. Future studies can evaluate, refine, or even refute the design principles in the tradition of scientific knowledge accumulation.

Table 4. IDMIS design principles[4]

Requirement	Design Principle (DP)	Aim and Actor/s	Context	Mechanism	Rationale
VUCA	DP1: Rapid response to a VUCA situation	Assisting designers and implementers to design and deploy the system quickly	Availability of prior source codes and system components	• Exploit and reuse existing components • Deploy improvised but viable systems	• VUCA situation requires quick response, release, and roll out
Infectious Disease Management	DP2: Understand the threat to public health	Allowing citizens, healthcare workers, and public health and government officers to understand the state of an infectious virus threat to public health	Public health system is centralized to some extent	• Automate data collection and processing • Informate up and down about pattern, speed, and distribution of the threat • Transform the processes and practices of all users	• IDMIS can ameliorate human capacity to recall potential exposure to an infectious virus by transforming the underlying tracing activities and processes • The epidemiological data can inform policymaking
	DP3: Manage the threat to public health	Allowing healthcare workers and public health and government officers to gain citizen participation in managing public health threats	Public health system is centralized to some extent and IDMIS use is voluntary	• Introduce data-driven measures to transform citizens' behaviors • Notify citizens about action recommendations • Automate predefined notification to citizens about action recommendations	• An IDMIS has different user groups and stakeholders, all needing evidence before deciding their next action • Users and stakeholders need updates on the development of the situation and

[4] Appendix J shows the connection between design principles and evidence.

					feedback on their actions
Sociopolitical	DP4: Preservation of citizens' sovereignty	Facilitating designers, implementers, and public health and government officers to preserve citizens' sovereignty	Democratic society	• Signal voluntary adoption • Signal the security of the information and the system in general through third party assurance and regulatory inscription • Use algorithmic privacy enhancement features to support desired privacy policies	• Non-adoption of IDMIS is often related to concerns about its purpose, security, data privacy, and data sovereignty
	DP5: Adoption at scale	Assisting public health and government officers to encourage citizens to quickly adopt the system	Democratic society	• Signal need and efficacy of the system • Signal impact of participation	• It is important to achieve a critical mass of users, but forcing adoption may lead to early discontinuance • Adoption campaign needs to be aligned with the cultural ethos and expectations of the society and in line with the VUCA situation at hand
	DP6: Public consolation	Enabling public health and government officers to provide comfort and consolation to the citizens	Democratic society, institutional trust deficit	• Use social embodiment and association strategies	• Enhancing the trustworthiness of an IDMIS is key to promoting acceptance and provide consolation in VUCA situations

6 Contribution and Conclusion

This paper set out to address the question of how information systems should be developed to manage a VUCA health situation. As this is a very complex problem, our aim was not to provide definitive prescriptive guidelines that will work under all conditions and circumstances. Instead, we sought to provide a nascent design theory that both researchers and practitioners can use as a foundation for IDMIS design in VUCA situations. We now turn to the research contribution and limitations of our work.

6.1 Research Contributions

IS studies have made valuable contributions to the development of prescriptive theories through construction of IS artifacts (Baskerville et al., 2018; Chandra Kruse et al., 2022; Gregor & Jones, 2007),. However, observation of an existing IS (and particularly IS-in-use) to generate design knowledge has received much less attention (Maedche et al., 2021). Our paper is one of the first that analyzes the temporal development of sociotechnical artifacts to develop nascent design knowledge. Thus, we address calls to examine the design choices of contact tracing systems (Rai, 2020) in keeping with Maedche et al.'s (2021) suggestion that "future design research should emphasize the researcher role of 'observation' more strongly" (p. 571). Our resulting contribution to research is theoretical, normative, and methodological.

Theoretically, we contribute an IDMIS design theory and six design principles to guide future design of IS that balances VUCA, public health, and sociopolitical requirements. These six principles can serve as a kernel theory (Gregor & Jones, 2007) for future IDMIS design initiatives, as well as for researchers who focus on IDMIS and other disease surveillance systems. Our design theory also contributes justificatory knowledge, thereby informing the purpose, scope, architecture, form, and function of IDMIS. Given the mutability of design theories from research to practice and the interpretive flexibility of practitioners in applying design principles developed by researchers, we believe that our IDMIS design theory is equally as valuable as design theories derived from creating a new IS artifact.

Our design theory also opens avenues for impactful future research, such as testing the actionability and usability of the design principles and forming the bases for comparative archaeological analysis of other IS.

Normatively, most existing studies on digital contact tracing focus on user adoption issues while disease surveillance system studies focus on potential and technical specifications. Our study expands the focus from users of systems to the underlying practices of “assembly, demonstration, and performance” (Suchman et al., 2002, p. 163), offering a fresh perspective for IS research. This shift in analysis shows that both citizens’ and public health workers’ interests need to be addressed by digital contact tracing. By providing the views and positions of a wide variety of actors—government, industry, politicians, professionals (health, IT, legal)—our work partially addresses Rowe's (2020) call to study “institutions … and industry actors positions and interests” (p. 4) beyond mobile apps. We add a sociotechnical perspective to discourse on the effectiveness of CoTIS (Rowe, 2020; Rowe et al., 2020) and extend the IS scholarship to design knowledge (Recker, 2021; Trang et al., 2020) for handling VUCA situations.

Our research also uncovers the importance of discursive design, aesthetics, and symbolic values in designing and theorizing CoTIS use as a collective action (Riemer et al., 2020). From a citizen perspective, COVIDSafe is a passive system with very limited interaction or user action after installation. There were as many stakeholders who questioned its appropriateness as those who advocated its use. Despite these issues, it was adopted by many people in Australia, not because of its effectiveness and instrumental value, but because of what it evoked for society, including: (a) the uncertainty of the pandemic and the emotion it aroused; (b) the government framing of the technology as a *quid pro quo* for lifting lockdowns; and (c) the call for collective community action to support health workers and to show patriotism suited to the Australian cultural context. These highlight the importance of sensory knowledge and symbolic meaning that users draw on to perceive the value of IS. Therefore, researchers studying IS and designers who are developing IDMIS should pay attention to both the imaginative and experiential aspects of IS.

Regarding our methodological contribution, while there are well-developed methods for design research that emphasize the researcher role of “creation” (Maedche et al., 2021), methods and approaches for the “observation” role of researchers are lacking. Our application of a design archaeology approach to systematically observe existing artifacts enables development of methods for studying digital artifacts by adapting or extending insights from organizational artifact and archaeology studies. We contribute to the “deployment” strand of design research in IS (c.f. Maedche et al. 2021) by applying a design archaeology approach (Chandra Kruse et al., 2019; Recker, 2021). We demonstrate the value of this approach for IS research through our post-diction (analysis of what happened) and prescription (suggestion on what should happen).

A design archaeology approach can address one of the key issues of “communicating artifact deployment research contribution” as it provides the means for “articulating the logic underlying the derivation of design principles extracted from observing and reasoning about the artifact in use” (Maedche et al., 2021, p. 570). In this way, we contribute to the question of how design knowledge can be constructed and communicated to others. We make the following recommendations based on our experience. First, the steps of a design archaeology analysis should be traceable as they affect a study’s claims of truth discovery. Researchers must demonstrate the process of their analysis and the knowledge construction process. We have demonstrated what we have extracted from the “archaeological site,” how that informs the analysis, and how that led to our IDMIS design theory.

Second, although we set out to study COVIDSafe using both the observation of the artifact (such as source code, app, UI) and the representation of the stakeholders, we often found ourselves relying on typical interpretivist methods as we drew meanings from the artifact, contexts, and languages used by stakeholders. This is consistent with Yanow's (2006) suggestion that “research that asks not only what artifacts mean but also how they mean draws, implicitly if not explicitly, on interpretive methods” (p.42). Thus, we recommend researchers to adopt the design/archaeological/artifact interpretivism paradigm.

The following table summarizes the unique contribution of this study *vis-à-vis* existing digital contact tracing IS studies.

Table 5. Unique contribution of this study

Area [References]	What we knew	This study’s unique contribution
Ex ante design of CoTIS (Naous et al., 2022; Riemer et al., 2020; Trang et al., 2020)	Suggestions about users’ preferences for different CoTIS design features. Importance of privacy-preservation in the design of CoTIS as well as how to govern CoTIS rollout and use.	The study goes beyond privacy considerations to offer design principles that account for a wider group of stakeholders and a range of material, social and discursive tensions that need to be managed to shape the form, function, scope, and purpose of an IDMIS.

Behavioral studies (Abramova et al., 2022; Goyal et al., 2021; Lin et al., 2021; Prakash & Das, 2022)	The diffusion of CoTIS raised concerns around mass surveillance and distrust. Studies identify several pandemics, demographical, personal, technological, and social factors, albeit inconclusive and equivocal, associated with citizens' intention to or use or resistance of CoTIS.	Our study offers a design theory that future designers can rely on when developing IDMIS. It balances VUCA, public health, and sociopolitical requirements with the dispositional affordances of IDMIS, i.e., management and control of infectious diseases. We go beyond citizens as the primary end users and consider other actors' concerns. Our study also highlights the importance of paying attention to discursive practices, aesthetics, and symbolism when designing IDMIS and theorizing about its adoption and use.
Critical studies (Fahey & Hino, 2020; Riemer et al., 2020; Rowe, 2020; Rowe et al., 2020)	National experiences of CoTIS rollouts demonstrate the varied pathways that governments have taken. Studies identify risks associated with erosion of civil liberty, digital solutionism, lack of understanding of the pandemic, and privacy as sources of failure. Studies produce inconclusive findings on the effectiveness of CoTIS in fighting COVID-19.	Our study offers an Australian perspective that reflects many of the same themes covered in previous studies. To those we add how the historical, cultural, temporal, and national contexts influence the views of stakeholders, the primacy of privacy, and how social and discursive design considerations such as regulatory provisions, social embodiment, and associations can be drawn upon to mitigate risks and lower the privacy threshold.
Calls for IS research/action (Karanasios, 2022; Rai, 2020)	Emphasize that the early success of CoTIS was unclear, thus the need for future research to inform the development of 'digital contact tracing 2.0' and answer research questions such as how to encourage rapid rollout of novel IS at a national level.	We address calls to examine the design choices of CoTIS. Our design archaeology analysis sets apart this study from previous CoTIS-related studies. Future studies can examine if our design theory reflects or can be expanded by research on other IDMIS.

6.2 Limitations

While the study makes valuable contributions, it has limitations. A key limitation of the study is that the data for the archaeological analysis are not gathered through interviewing. Analyzing the views of practitioners (Bawack et al., 2021) and researchers (Webster & Watson, 2002) is an accepted method for knowledge contribution in IS research. Our data and approach, which is consistent with artifact and archaeology studies (Rafaeli & Pratt, 2006; Recker, 2021; Ulrich & Pearson, 1998), therefore make sense for developing an IDMIS design theory. Indeed, our approach has the advantage of accessing hard-to-reach data sources. Nevertheless, despite the best effort and care in interpreting the data through cross-validating, triangulating, and verifying the accuracy of statements and quotes from critical stakeholders from multiple sources, we recognize the limitations of the data and the potential for (mis)interpretations.

On a related note, we do not claim to have covered all materials about COVIDSafe during the study period. For instance, we didn't cover social media posts. The source code, screenshots, and documents we collected and analyzed can only be considered as a representative sample. Since our design theory is derived from COVIDSafe and the Australian context, we caution against simple generalizations to other contexts. Another limitation is the lack of well-developed and tested guidelines on how to undertake design archaeology analysis and the type of knowledge contribution possible from artifact "deployment" design research. We follow Maedche et al. (2021) to develop our IDMIS design theory inductively to encompass "high level principles and their justification". We leave testing the actionability, usability, and efficacy of the theory and principles for further research.

The problem we addressed was very complex, involving multifaceted sociotechnical design issues: the IS application itself, its deployment context, and the overall VUCA situation, all of which required tailored strategies. We had to balance between breadth and depth to formulate the set of design principles based on the insights gathered in our design archaeology. In the end, we opted for breadth, with the aim of contributing sociotechnical knowledge in the "axis of cohesion" of the IS discipline (Sarker et al., 2019). This, however, comes at the cost of depth for each specific issue (e.g., the nature and antecedents of the sociopolitical requirement in our design theorizing). We recognise this limitation and believe that researchers can learn about the three areas of requirements related to IDMIS design both from our method and the design principles, and then advance the knowledge in the spirit of scientific knowledge accumulation.

6.3 Conclusion

COVID-19 posed unprecedented socioeconomic challenges for researchers, policy makers, and practitioners. CoTIS were promoted as one of the early digital interventions for fighting the pandemic but developing them was very challenging. Digital artifacts, such as CoTIS, have representational and communicative power (Gregor & Jones, 2007; Recker, 2021). Systematically observing them and the designers', users', and other stakeholders' "vocabularies and gestures" (Yanow, 2006, p. 57), we can identify "good" and "bad" design choices leading to inductively developed design theories. By undertaking a design archaeology analysis of the historical, artifact, stakeholders, aesthetic, instrumental, and symbolic dimensions of COVIDSafe, we developed an IDMIS design theory that researchers and practitioners may consider in guiding the design of IS in other VUCA situations. Our work shows design archaeology analysis as one source of justificatory knowledge construction for future DSR research projects. This would entail identifying and examining a similar class of IS artifact-in-use to produce prescriptive design principles.

The study also draws attention to a wider group of stakeholders and a range of material, social, and discursive construction tensions that need to be managed to shape the form, function, scope, and purpose of IDMIS. IS researchers need to focus not only on citizens' issues but also the experiences of other actors and stakeholders in developing/testing theories on IS developed to manage VUCA situations. Practitioners can use our design principles to enhance their understanding of the nuances of designing IDMIS to manage and control infectious diseases under VUCA situations.

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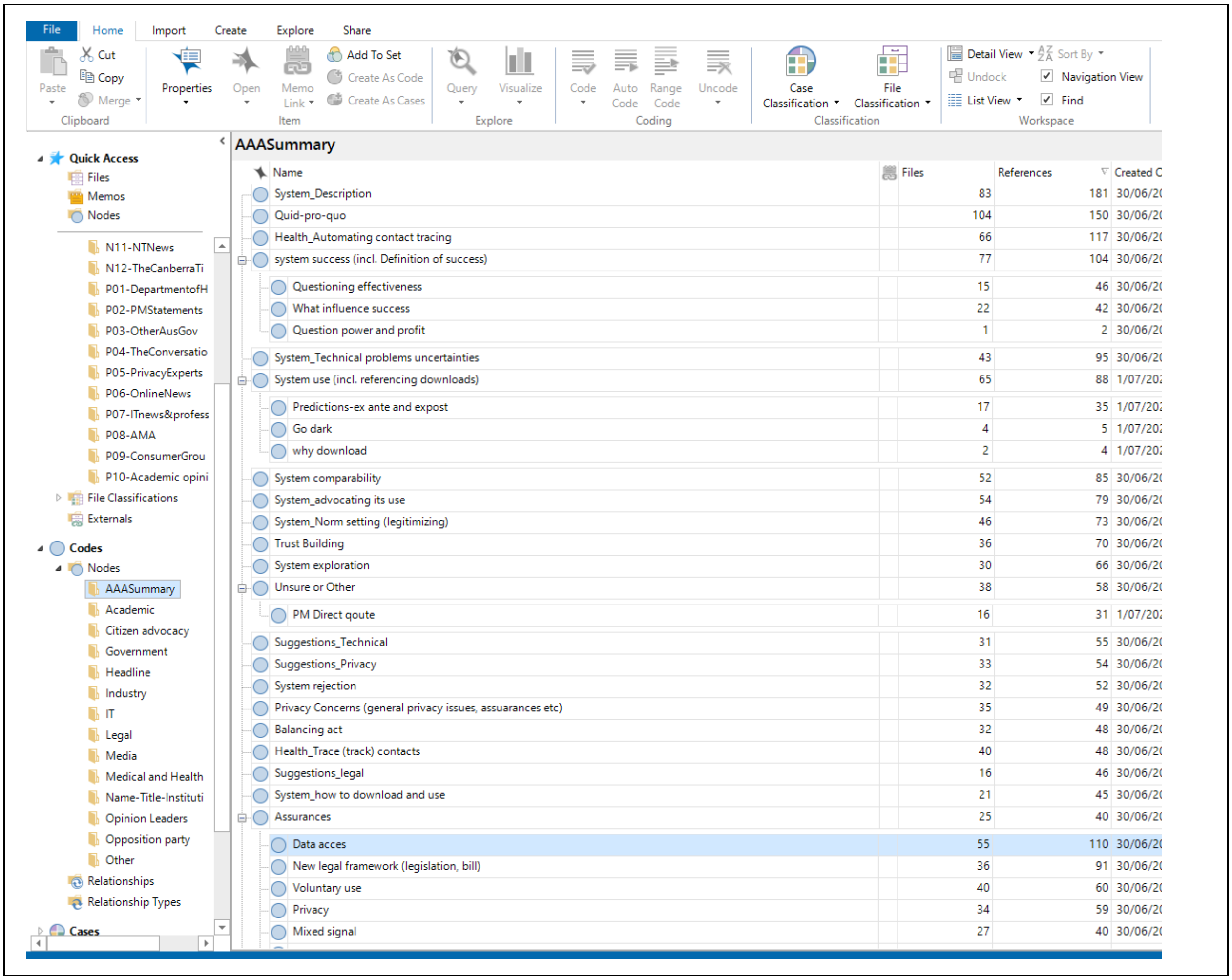
Appendix A: Inter-coder reliability analysis

	Round 1		Round 2	
	Kappa score	**No. of codes used**	**Kappa score**	**No. of codes used**
File 1	0.74	12	0.91	12
File 2	0.61	30	0.94	14
File 3	0.72	15	0.96	12
File 4	0.56	23	1.00	13
File 5	0.69	13	1.0	10
	Average Kappa score: 0.66	Avg codes used per file: 18.6	Average Kappa score: 0.96	Avg codes used per file: 12.2

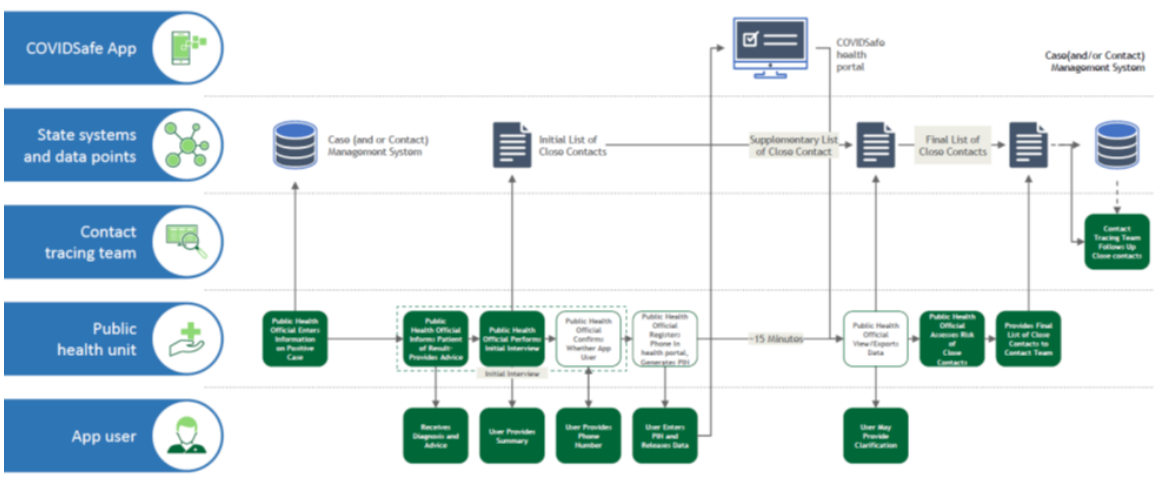
Appendix B: Coding tree example



Appendix C: Examples for the description of COVIDSafe

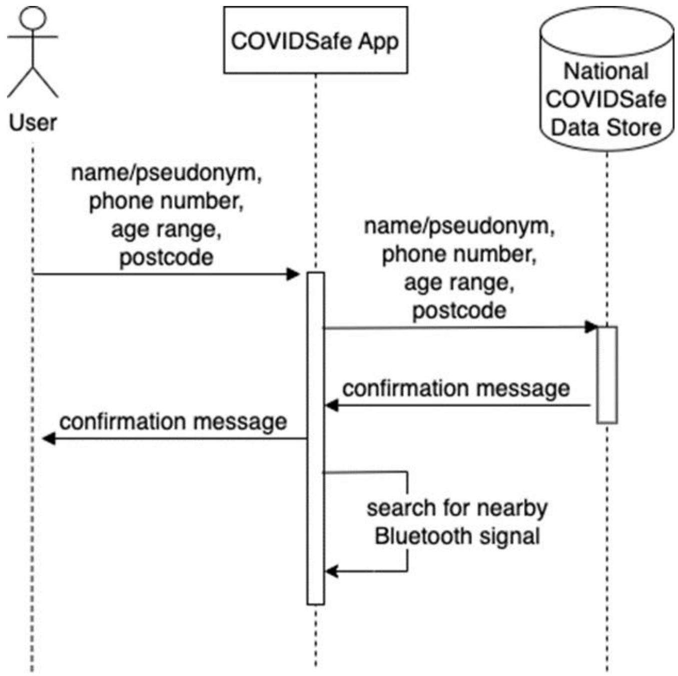
Examples of text logs	Open code	Archaeology analysis dimensions	Design theorizing insight
"The app will use Bluetooth to communicate with other smartphones"	System description	Historical, Artifact description	Context (availability of technologies)
"The collection of data is minimal — a name, a phone number, a postcode and an age range are the only information gathered"	System description	Artifact description	Requirement
"When two smartphones come within 1.5m of each other, and remain so for 15 minutes, an interaction or "digital handshake" will be recorded on each phone."	System description	Artifact description	Mechanism (automate), privacy, trust
"No location data was collected, and this was tracing, not tracking."	System description	Artifact description	Requirement Privacy, Trust
"Contact tracing apps generally store 14-21 days of interaction data between participating devices"	System description	Artifact description	Mechanism
"The data on the phone is encrypted and cannot be seen by the owner or any other person. It is illegal for any law enforcement, government agency or court to try to access the data. The data sent to the national store is deleted at the end of the pandemic"	System description	Artifact description	Requirement Privacy, Trust
"If you are diagnosed with COVID-19, a health official will ask whether you would like to share your contacts from the past 21 days. If you consent, this data is sent to a national store and then provided to relevant state officials. The federal government does not see the data "	System description	Artifact description	Context, Privacy, Trust,
"The app uses less than 1MB of data per day. It does not need to be connected continuously to the Internet to work, but it does need to connect occasionally to retrieve new temporary IDs from the server. This helps to protect your privacy and to collect anonymised analytics data."	System description	Artifact description	Application layer

Overview of COVIDSafe app Data Flow

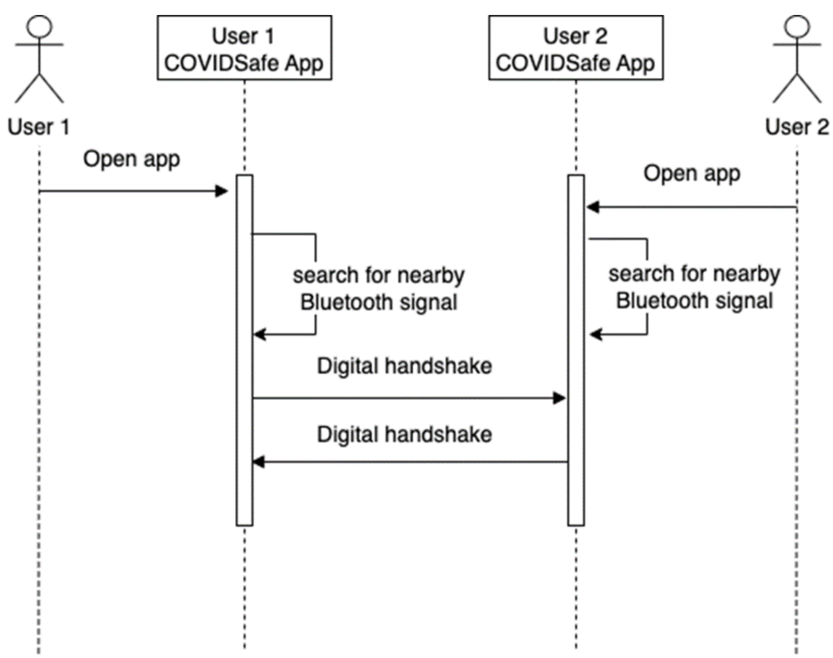


Source: https://www.health.gov.au/sites/default/files/documents/2021/07/report-on-the-operation-and-effectiveness-of-covidsafe-and-the-national-covidsafe-data-store_0.pdf

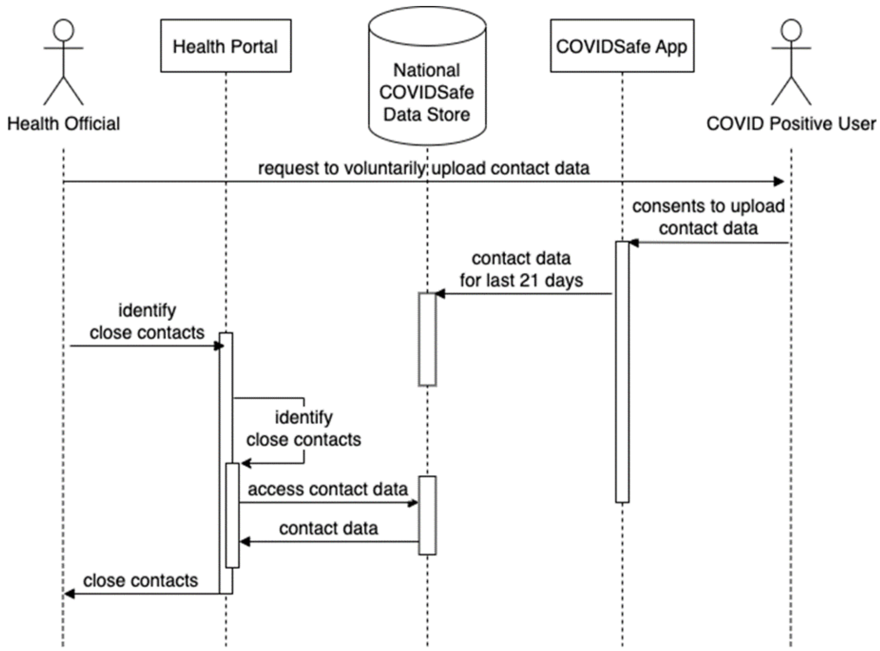
The user interface layer of the COVIDSafe app



The data collection layer of COVIDSafe app



The notification layer of COVIDSafe app



Appendix D: Examples for stakeholders' perspective of COVIDSafe

Stakeholder	Examples of text logs	Open code	Archaeology analysis dimensions	Design theorizing insight
Designers	"Testing the code of the technology that was used in Singapore… an app called TraceTogether… would not "cut and paste measures from other places, which have completely different societies."	system exploration	Historical, stakeholders	Aim, Actors Requirement Context
	"The Australian Government is investigating digital methods of tracing COVID-19"	system exploration		
	"Prime Minister Scott Morrison suggested …the government was not won over by Apple and Google's proposal."	system exploration		
	"A clause in the legislation — which forces state health authorities to delete all the data they have from COVIDSafe will be activated"	sunset clause	How designers envisioned to develop CoVIDSafe,	Aim, Actors, Context
	"***What we've done is actually strip back the function so as there's one job, and one job alone****, and that is if you are positive, to be able to make that available only to the state public health authorities, with nobody else having access and to make sure it is voluntary" (Prime Minister, Press Conference Apr 27)*	purpose		
	"The federal government wants millions of Australians to download the app"	advocating use	Adoption practices envisioned by designers	Context, Mechanism, Rationale
	"Australians had already "crossed the Rubicon" of enforced social isolation, **making it a relatively smaller step** to consent to greater **electronic monitoring** to tackle COVID-19"	privacy reconstructing		
	"**Keep the app open and notifications** on when you're out and about, especially in meetings and public places."	system description	Use practices envisioned by designers, History, artifact	
	'**The app is part of the three key requirements for easing restrictions:** Test, Trace and Respond'	quid-pro-quid		
	"In relation to signal strength, essentially **we encourage you to have it on.**"	system description		
Citizens	"I gave up my privacy a long time ago, I don't care" [Herald Sun, April 19]		Practices envisioned by citizens aesthetic, symbolic	Actors, Context, Mechanisms
	"I'm **not doing anything illegal, but I don't want anyone else trolling through my personal information**. Especially when our Anzacs have fought hard for our freedoms."	system rejection		
	"I treasure **the government knowing as little** about me as possible"	system rejection		
	"It is about **helping our public health officials** do their job and it is a no-risk, highly secure, very safe app."	automating tracing	Citizens' perception, aesthetics, instrumental	
	"At least this app might **stop us from dying in future**"	app as solution		
	"I know many are concerned about the invasion of privacy, but let's have some perspective. If we were overly preoccupied with privacy wouldn't fewer of us use Facebook, Twitter, Google, or Instagram?"	Privacy reconstructing		
	"If you are meeting someone you really don't want anyone to know about, maybe leave your phone at home."	go dark	Use practices	
	"The definition of COVID app data should be expanded to include all data collected by and associated with the app to ensure it covers the whole chain of data from a user's smartphone, via the Commonwealth-run central server, to a contact trace in a state health agency"	suggestion		
Medical and health professionals	"The chief medical officer's advice is we need the COVIDSafe app as part of the plan to **save lives and save livelihoods**,"	app as a solution	Instrumental, symbolic	Actors, Requirements, Mechanisms, Application layers
	"Without this technology, health officials **have to rely on people being able to remember** who they have been around, and being able to provide contact details for those people" [Chief Medical Officer]	Automating contact tracing	Instrumental, symbolic	

	"I'm not a tech expert, but apparently it uses Bluetooth handshake, which is the only handshake we're allowed." [Australian Nursing and Midwifery Federation secretary]	advocating use	Aesthetics, instrumental, symbolic	
	"The app **simply automates a significant component of the current manual process** of tracing who has come into contact with COVID-19. [Australia Medical Association president]	Norm setting	Instrumental	
	"Privacy, technical, and practical issues must be assured, and the inevitable challenges in the app's rollout need to be anticipated and prevented [Australia Medical Association president, April 26, 2020]	Privacy suggestion	Aesthetics	
	"We've got our contact tracing **capacity ramped** up fully, we've got our COVIDSafe app" [Australia Medical Association president]	quid-pro-quid	Instrumental, symbolic	
	"This has **helped bring forward** national cabinet consideration of easing restrictions by a week." [Chief Medical Officer]	quid-pro-quid	Instrumental, symbolic	
	"As an epidemiologist, I think **anything that speeds up contact tracing is incredibly helpful**[5] for shutting down the spread of such a highly contagious virus as COVID-19" [Epidemiologist].	system exploration	Aesthetics, instrumental, symbolic	
Other Stakeholders	"Trade union members are not threatened by the idea of collective action. We understand people working together are more powerful than individuals acting alone. We believe in the common good." [National Secretary of the Rail, Tram, and Bus Union]	common good	Symbolic	Actors, Context, Requirements, Mechanisms
	"Apps like TraceTogether "**pose a nightmare from a privacy perspective**" [Academic]	system comparability	Aesthetics	
	"The impetus for the creation of this app hasn't come from politics but from science. It wasn't the PM's idea. It emanated from the chief medical officers and health experts who need a way to track the spread of the virus and cleverly"	Future proofing	Historical, Aesthetics	
	"Bluetooth signal-strength (RSSI) is a poor proxy-measure of distance between devices, because it is affected by a great many factors, some of which commonly arise in mainstream use-cases." [IT Professional and Academic]	Technical problem	Artifact, Aesthetics	
	"The way this app has been released, with incomplete information, incomplete protections and no consultation, is very disappointing," [Australian Privacy Foundation Chair]	Rollout, citizen advocacy	Aesthetics	
	"One of the key challenges of developing the COVIDSafe tracing app is the need to have a broad range of expertise and perspectives involved – public health, technology, security, privacy, human rights, digital inclusion, communications and community interests all need to be considered within a tight timeframe." [ACCAN]	development environment	Historical, Aesthetics	
	"Anything that helps us wrestle COVID-19 to the ground is a plus. Any privacy any of us had pretty much disappeared when we started using mobile phones, searching online, buying stuff from Amazon or whatever," [Australian Nobel laureate and Immunologist]	Norm setting, reconstructing privacy	Instrumental, symbolic, aesthetics	
	"It strikes me as self-indulgent to put one's privacy principles first when, if we just chilled a little, we might deploy an innocent temporary smartphone app to help our public health system." [The Age]	common good	Aesthetics, Instrumental	
	"The app may well mark the start of fresh tension between civil liberties and lifesaving not seen since policies made after the September 11 terrorist attacks in 2001." [The Age]	privacy infringement	Aesthetics, symbolic	
	"The legislation that governs the app must clearly state that its use is limited to minimising the danger of community transmission of the COVID-19 virus. "A sunset clause is essential, but we caution that these have previously been inserted into anti-terror laws, only for them to be later removed,	legal suggestions	Aesthetics. Historical	

[5] Emphasis added

	proving that they do not provide adequate protection." [Australian Lawyers Alliance National President]			

Appendix E: Examples for aesthetics dimension

Text	Open code	Archaeology analysis dimensions	Design theorizing insight
"When **you first download the app, the only thing shared is your name, age range and your postcode**, which goes to a national store and that's how you get allocated your unique identifier,"	System description	Aesthetics, Artifact	Application layer, Requirements
"It's **not unlike the "tap and go"** technology used to pay wirelessly with smartphones at the checkout. "	System description	Aesthetics, Artifact	
"To work, the app must be left open and allowed to run in the background"	System description	Aesthetics, Artifact	
"Installing the COVIDSafe app is simple"	System description	Aesthetics	
"**If you delete the app**, this will delete all app information from your phone. The information in the storage system will not be deleted until the end of the pandemic, however if you would like it to be deleted sooner, you can request this online through a data deletion form."	System description	Aesthetics, Artifact	
"If you are contacted by a state or territory health official conducting contact tracing you will be advised about what steps to take, including the need for self isolation and testing."	System description	Aesthetics, Artifact	
"COVIDSafe is pretty innocuous. It works by anonymously logging each time another COVIDSafe user comes into range for a few minutes."	System description	Aesthetics, Artifact	
"COVIDSafe only sends SMS messages to give you your verification PIN during registration or if you are consenting to upload information to the national information storage system." [May 8, 2020]	System description	Aesthetics, Artifact	
"We tested the app to make sure it meets colour contrast standards has the best text size has alt text for images"	System description	Aesthetics,	

Appendix F: Examples for instrumental dimension of COVIDSafe

Text	Open code	Goal category	Design theorizing insight
"a contract tracing app **that will track Australians and notify them** if they have come into contact with someone with a confirmed coronavirus case." [April 20, 2020]	advocating issue	Automating, contact tracing	Requirements, Application layers, Mechanisms
"We need a greater degree of **tracing capability** for contacts, and that can happen much more quickly than it does now [April 14] … we need the COVIDSafe app as part of the plan to **save lives and save livelihoods** [April 18] … This is the **ticket to ensuring** that we can have **eased restrictions** and Australians can go back to the lifestyle and the many things that they previously were able to do, and this is important" [Prime Minster Scott Morrison]	system exploration	Automating, Developing capability; Easing restrictions	
"The app **simply automates a significant component of the current manual process** of tracing who has come into contact with COVID-19" [Australian Medical Association (AMA) President, Tony Bartone, AMA Press Release, April 26]	automating contact tracing	Automating contact tracing	
"The government believes **40 per cent of Australians will have to download** the app for it to be effective." [April 20, 2020]	system success	Mass adoption	
"The app, which will use the source code for Singapore's TraceTogether software, will allow **health authorities to alert Australians** if they have come close to positive COVID-19 cases [April 15]	system description	Efficiency & accuracy of contact tracing	
"To help our health workers, to protect our community and help **get our economy going** again." [April 20, 2020]	social duty	Efficiency of contact tracing	
"National cabinet has endorsed **the app aimed at making it easier to track people** who have been in contact with COVID-19 sufferers." [April 22, 2020]	norm setting	Efficiency of contact tracing	
"Health authorities have **used the COVIDSafe app to track a coronavirus case** for the first time, with the program helping to find a close contact that may not otherwise have been found."	system success	Accuracy of contact tracing	
"A new tracking app is likely to be available in Australia within weeks, offering faster tracing of COVID-19 contacts and a potential early release from economically crippling social restrictions." [April 15, 2020]	automation	Easing restrictions,	
"It's another tool we need **to get back to normal** as much as we can,"	quid-pro-quo	Returning to normal	
"That **is the ticket to opening up our economy** - to getting people back into jobs and getting businesses open again," [Mr Morrison May 2, 2020]	quid-pro-quo	Opening the economy	
"When it comes to universities, our priority is opening campuses for face-to-face learning for domestic and international students already in the country and **mass downloading of the app will support that process.**"	quid-pro-quo	Opening the economy	
"The app is **a potential game-changer** in the fight against this deadly disease." [May 12, 2020]	system description	Suppressing COVID-19	
"This app would have one purpose — **to suppress the virus** — and once the virus has been sufficiently controlled, we can all delete it from our phones." [April 20, 2020]	seeing off covid	Suppressing COVID-19	

Appendix G: Examples of "symbolic meaning" for COVIDSafe

Text	Open code	Symbolic meaning	Design theorizing insight
"The health experts and governments will do what they've promised: more testing and a rapid response to control outbreaks. **But the last part - downloading the COVIDSafe app - is up to us**."	Social duty, protect Australia	Team Australia	Socio-political requirements
"Open up Australia... let's make it App-en"	Social duty		
"Commonwealth Bank chief executive Matt Comyn has thrown his weight behind the government's controversial plan to track the community spread of the coronavirus via mobile phone app, arguing the technology will lead to "getting more of our lives back sooner."	advocating use		
"Much of the Business Council of Australia elite were happy to show they were in lock-step."	advocating use		
"More than 300 of Australia's leading technology professionals have voiced their public support of the COVIDSafe app… So, what we wanted to do in t**his Team Australia moment,**"	Team Australia		
"In the absence of a medical vaccine, you could think about contac**t tracing as a digital vaccine** with our contact data being the virtual antibodies."	app as a solution	Digital Vaccine	Infectious disease management requirements
"The technology was important in further **suppressing the virus** and allowing everyone to return to normal life."	app as a solution		
"This is a health app, not a surveillance app. **This is about saving lives** and getting Australia and Australians back to normal."	app as a solution		
"Downloading the app is like putting on a broad-brimmed hat and sunscreen to go out into the sun."	app as a solution		
"Groups were largely supportive because the app is seen as k**ey to getting the economy back up**.'	advocating use	Road to recovery	Context (democratic society)
"Like returning auctions to the public arena but only letting people attend **if they have the COVIDSafe app** on their phone	advocating use		
"By sticking to the plan, we are o**n the road back**. To finish the job together, let's get COVIDSafe."	social duty		
"The app is a key weapon in the pandemic war"	app as a solution		
"Encourage their staff to download the app, with **industry hoping it will fast-track the reopening** of businesses that have been forced to close	advocating use		
"I don't want them **tracking** me, I don't trust the government,"	system rejection	Digital surveillanc e	Context,
"The TraceTogether app **does not provide sufficient privacy from the Central Authority**. …The app can potentially be (mis-) used for surveillance."	system comparability		
Privacy advocates are already fanning fears about a government-run app having so much data about daily movements."			
"It is way too Big Brotherish for me. I have a normal personal life but it's my personal life ... "This is the realms of science-fiction." [Deputy Speaker of the House of Representatives]			
"I believe in the liberties of this nation that I have the right to choose to use it or choose not to use it. …Unless we get to a nation which says governments can tell you things and whether you like it or not, they don't believe in choice."	System rejection		
"This is a health app, not a **surveillance** app"	app as a solution		

Appendix H: COVIDSafe system activity statistics

	26 April 2020 – 15 November 2020	16 November 2020 – 15 May 2021	16 May 2021 – 25 November 2021	Total (as of 15 November 2021)
Total cumulative registrations	7,176,056	7,418,328	7,763,991	7,763,991
Number of COVID positive COVIDSafe user who consented to upload their data to NCDS	735	44	13	792
Number of digital handshakes uploaded to NCDS	1,450,000	202,100	331	1,652,431
Number of potential contacts identified from close encounters	2,579 potential close contacts identified from more than 35,939 encounters	248 potential close contacts identified from >1,729 encounters	2 potential close contacts identified from 9 encounters	2,829 potential close contacts identified from > 37,677 encounters
Source: Australian Government (2021a) & Australian Government (2021b)				

Appendix J: Linking the evidence to design principles

Evidence Archaeology dimension	Design theorizing component
Historical, Artifactual, and Instrumental dimensions	**Aim and key requirements of IDMIS**
Stakeholder dimension	**Actors**
Artifactual, Instrumental, Aesthetics dimensions	**Key application layers**
Historical dimension: Technology option Exploitation vs. exploration Discursive design practice	**DP1: Rapid response to a VUCA situation**
Stakeholder dimension Artifactual and instrumental dimensions: Data collection, data processing and analysis Automate, informate, transform	**DP2: Understand the threat to public health**
Stakeholder dimension Artifactual and instrumental dimensions: Representation, notification Automate and transform	**DP3: Manage the threat to public health**
Historical dimension: Public health vs. civil liberties Trust Artifactual dimensions: Privacy policy in data collection, data processing and analysis Overall cybersecurity measures	**DP4: Preservation of citizen's sovereignty**
Aesthetics dimension: User experience, identity Historical dimension: Cultural alignment Trust Symbolic dimension Instrumental dimension: Informate and transform	**DP5: Adoption at scale**
Symbolic dimension Historical dimension: Cultural alignment Discursive design practice	**DP6: Public consolation**

About the Authors

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