

Characteristics and determinants of population acceptance of COVID-19 digital contact tracing: a systematic review

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Abstract. *Background and aim:* As recently outlined in the WHO-ECDC Indicator framework to evaluate the public health effectiveness of digital proximity tracing solutions, one of the main barriers to digital contact tracing (DCT) is population acceptance, which, in turns, is influenced by digital literacy, attitudes and practice. DCT came to public prominence during the COVID-19 pandemic but evidence on its population acceptance have not been comprehensively analyzed. *Methods:* We carried out a systematic review (PROSPERO: CRD42021253668) following the PRISMA guidelines. Original studies reporting on different measures of population DCT acceptance were included. *Results:* The systematic review was based on 41 articles meeting our a priori defined inclusion criteria, comprising a total of 186144 surveyed subjects, 50000 tweets, 5025 Reddit posts and 714 written comments. Data extraction and synthesis required qualitative outcome grouping, performed ex-post, in 14 different benchmarks components. They constitute a narrative analysis of actionable points for public health policy. *Conclusion:* Population acceptance is a key component of DCT effective adoption and, ultimately, infection control during infectious diseases outbreaks. Assessing DCT acceptance's determinants in different settings, populations and cultural contexts it is of fundamental importance to inform the planning, implementation and monitoring of public health interventions. The results of our in-depth qualitative and quantitative analysis should guide future research aimed at exploring how digitalization can serve people-centred care. (www.actabiomedica.it)

Key words: digital contact tracing, acceptance, systematic review, COVID-19

Introduction

Contact tracing (CT), is the practice of identifying people who have recently had contact with someone who has been diagnosed with an infectious disease in order to treat or confine them. Digital contact tracing (DCT) is an enhancement of analog CT. It is based on the digitalization of contact logging. The most diffused approach is based on the privacy-preserving exposure notification system by Apple and Google (1). The system works by exchanging unique, temporary identifiers among people spending enough time in close proximity. If a recent proximity event with a diagnosed case were to happen, the system

would match the positivity notice with the user's beacon. Then, the smartphone-stored identifiers would be matched on-device (to ensure privacy) with the positive case, notified by the centralized server, prompting self-isolation and eventual further steps.

Based on a mix of qualitative and quantitative evidence, this systematic review aims to evaluate the barriers and levers to access DCT technologies, benchmarked under the umbrella term "acceptance". For instance, how does privacy affect DCT uptake? Or, what is the role of personal attitude toward technology? The phrase "DCT acceptance" necessarily holds a large number of topics due to the complex impact of new, more personal and potentially invasive, approaches to

contact logging. The broadness and novelty of the concept cause the lack of an evaluation framework, forcing a hybrid approach synthesizing surveys, interviews and appropriate modeling.

One of the first milestones in the DCT space was the article of Ferretti and colleagues (2). Their hypothesis about the success of DCT is backed up by solid epidemiological modeling that displays a steeper decline in the epidemic function with the shortening of the intervention delay (from symptom notification to case isolation and quarantine). The shortening is made possible by the instantaneous approach of DCT, which realistically is a bit slower than modeled but still faster than a manual approach. Of course, modeling is now backed by real-world data on digital epidemic control, as shown in the systematic review by Grekousis and colleagues (3). They review studies from several countries that have deployed DCT, most of the time together with manual CT. A positive impact on epidemic control by DCT is always registered.

Looking at DCT effectiveness implies evaluating acceptance, the true driver behind the voluntary action of sharing personal data. The groundwork laid by Moreno López and colleagues estimate uptake of DCT tools as low as 20% to reduce peak infection incidence by 30% (4). Logically, increased uptake enhances infection control (5). Looking at acceptance or its benchmarks can nuance DCT effectiveness and open the door to a better understanding of its uptake.

Sharing personal data, especially healthcare ones, in the era of more privacy-aware citizens, poses a challenge that public health officials must be ready to accept. The challenge is to consciously develop digital solutions that are tightly bound by law and respectful of public concerns.

Methods

This systematic review without meta-analysis follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (6). The protocol is registered in PROSPERO (CRD42021253668). This study was based on data collected from publicly available bibliometric

databases and did not require ethical approval from our institutional review board.

Aims

The aim of this systematic review is to investigate the acceptance of DCT, benchmarked via indicators of uptake, usage, interaction and general sentiment or perception. We focus on both qualitative and quantitative outcomes due to the complexity of the acceptance dimension.

Search strategy

Studies were identified by searching the electronic databases PubMed, Embase, Web of Science and The Cochrane Library. The search strategy was first developed in PubMed using a combination of free text and Mesh terms identifying: i) the concept of digital CT, and ii) its interest and implications in the COVID-19 pandemic. Such search strategy was then tailored to the other database search codes. Complete search strategies are available on the PROSPERO protocol. We restricted to publications: i) from 2020 onward; ii) written in English.

Outcomes of interest

We included all studies reporting original qualitative or quantitative data on DCT acceptance Measures/indicators of acceptance were identified by breaking it down into fourteen core concepts: knowledge of the technology (either DCT itself or the tools—eg, smartphones, used for it), willingness to download the DCT app, accessibility of the technology, download percentages, adherence/compliance to the technology, self-efficacy and community empowerment (so both altruistic and self-centered sentiments at the root of download or compliance), user profiling, privacy, government trust/surveillance, cybersecurity, social media sentiment, communication, eventual additional features and reported usefulness.

All original study designs were included, no age nor region-specific limitations were in place. Mathematical models were excluded. We restricted to publications: i) from 2020 onward; ii) written in English.

Quality assessment

Two review authors independently assessed bias risk for each of the included studies using the RTI (Research Triangle Institute) revised item bank (7,8), evaluating risk of bias and confounding. Discrepancies were assessed and resolved by the two senior authors.

Data extraction and management

Two authors (LP, EM) independently assessed identified papers for eligibility in a two-step procedure; a first screening was done based on title and abstract, while complete texts were retrieved for the second screening. Disagreements were addressed at both phases through discussions with two senior researchers (AO, MG). Data from chosen publications were retrieved and tabulated separately by two researchers (LP, EM), who were overseen by two senior research (AO, MG), in order to undertake the evaluation of study quality and evidence synthesis.

Data extraction was performed using a form for the assessment of study quality and evidence synthesis, including: authors, type of study, nation, number of subjects, population, representativity, sample scoping tool and DCT technology acceptance benchmarks. The benchmarks were further divided in positive, negative and neutral and declined under the following categories: i) knowledge of the technology, ii) willingness to download the app, iii) accessibility of the technology, iv) download percentages, v) adherence/compliance to the technology, vi) self-efficacy and community empowerment, vii) user profiling, viii) privacy, ix) government trust/surveillance, x) cybersecurity, xi) social media sentiment, xii) communication, xiii) eventual additional features, xiv) reported usefulness. The two review authors extracted data independently, discrepancies were identified and resolved through discussion (with the two senior authors). No meta-analysis is planned for this systematic review. According to the Synthesis Without Meta-Analysis guidelines (9), the following were reported independently by the two researchers and reviewed by senior authors, any disagreement was discussed thoroughly. The following operative checklist was followed: i) was study tabulation for any reported acceptance measure; ii) tabulated measures were divided according to positive, negative and neutral declinations;

iii) outcome effects were further synthesized and grouped under fourteen categories; iv) researchers always prioritized nation-wide, general population studies, then region-specific and/or specific population ones; v) outcome heterogeneity required a narrative synthesis of extensive qualitative data; vi) the risk of bias was assessed by the RTI revised item bank; vii) summarized data from each included study is available in Appendix A, full extraction data is available upon request.

Results

Searching the chosen electronic databases yielded one thousand two hundred and one records. After duplicates removal, titles and abstracts of 789 records were screened. 468 studies were eliminated because they were unrelated to the study issue, while the remaining 321 were evaluated for eligibility. The systematic review includes 123 studies after a second full-text screening. PRISMA flowchart in Figure 1 (6).

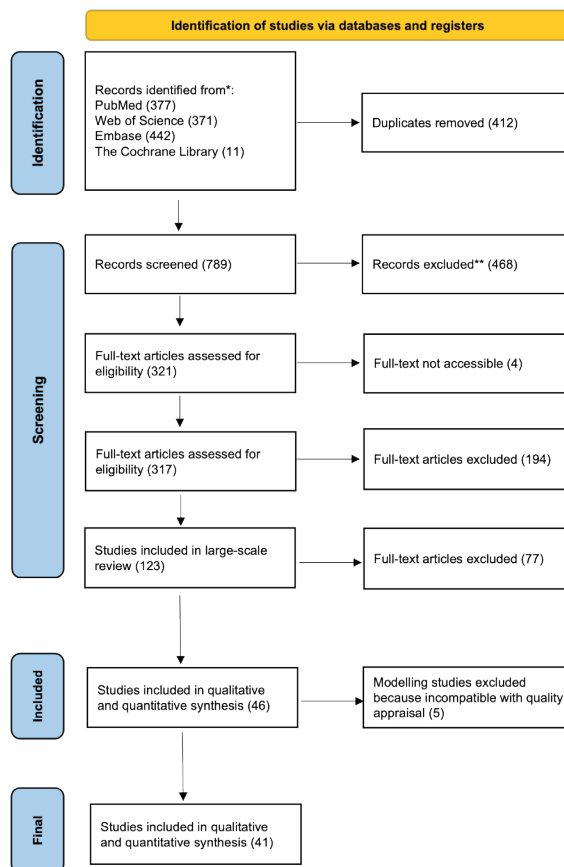


Figure 1. the PRISMA flowchart for literature screening

18 papers belong to Europe, 9 to America, 8 to Asia, 4 to Australia and 2 to Africa. Twenty studies are cross-sectional, 4 text analyses, 2 longitudinal cohort studies and 2 cross-country studies. All the others were unique study designs.

Thirty-five papers referred to the general population, 7 to a specific population. Although only 15 studies were representative, we decided to also include studies with specific populations to avoid glossing over underrepresented minorities, refer to Table 1 for the summary of included studies. The Table 2 shows a brief benchmark overview to navigate the core concepts.

1. Knowledge of the technology

No clear data were available about DCT knowledge among the general population, although most of the papers somehow referred to it throughout their discussion. This dimension often overlapped with that of broader acceptance, making it difficult to infer independently.

In their representative study of French Health Science students, Montagni and colleagues found a percentage of 77.3% of the knowledge of DCT (10). This result is meaningful when related to the fact that 66% of those who had heard about the app did not download it.

2. Willingness to download the app

The “willingness to download” dimension measures the intention to effectively download the app on the device, the idea and perception of it, or its basic acceptance in terms of approval/refusal and tolerance with no further declinations. It is absolutely the most examined and accurately reported outcome.

16 studies and other 3 studies reported at least one or more records about it for the general and specific population, respectively.

As for the general population, 18 results were declined as positive, 7 as negative, none as neutral. Willingness percentages ranged from 18.5% to 95%, boosted by the idea of additional self and privacy safeguarding options. “Willingness not to download” percentages ranged from 20.40% to 66%. As well-scoped by Zimmermann and colleagues, surveillance,

democracy, privacy and positivity stigma issues were the main drivers of reluctance in DCT app adoption (11). In Garrett and colleagues’ work, 58% of effective intention to download was found, lower than the predicted acceptability (62-70%), identifying a first acceptance gap (12).

Looking at specific populations, willingness percentages similarly ranged between 60% of registered UK National Health Service (NHS) users (13) and 90% of young Taiwanese adults (14).

Among negative results, additional concerns about effectiveness, due to the limited diffusion of the apps, are also taken into consideration by Montagni and colleagues (10).

3. Accessibility of the technology

Before acceptability, it is necessary to focus on the real accessibility of these apps among the general population. From 6 studies dwelling on this essential aspect, we selected 7 appropriate results, 6 of which later declined as negative. The isolated positive record came from Italy, where, according to Giansanti and colleagues, 100% of the young and 64.3% of the elderly had a smartphone, yet the study was not representative (15).

On the other hand, barriers to access, mainly caused by socioeconomic status, education and digital divide, were identified in 5 studies (from both Europe and Asia) (16–20) in a percentage ranging from 17.3% (19) to 62% (16). These included lack of a smartphone, lack of adequate technical equipment or incompatibility issues.

Furthermore, the lack of a compatible phone was expressively reported in similar percentages (22.8-28%) by two different European representative studies (17,20) to be one of the leading reasons for not downloading DCT applications.

Referring to the specific population of UK NHS users, Bachtiger and colleagues reported that 47% of 80+ years old would have not downloaded a DCT app (13).

4. Download percentages

In view of these preliminary data of knowledge, willingness and accessibility, we examined concrete percentage data about effective downloading.

Table 1. Included studies summarization (* NA = Not Applicable; † PRAW = Python Reddit API Wrapper)

Authors	Type of study	Nation	n° of subjects	Population	Representative	Tool
Jerome et al.	Cross-sectional	Canada	317	Healthcare workers	No	Online survey
O'Callaghan et al.	Cross-sectional	Ireland	8088	General population	No	Online survey
Rodriguez et al.	Population-based controlled experiment	Spain	10000	General population	No	Online survey
Altmann et al.	Cross-country survey	France, Germany, Italy, United Kingdom, United States	5996	General population	Yes	Online survey
Walrave et al.	Cross-sectional	Belgium	1500	General population	Yes	Online survey
Zhang et al.	Cross-sectional	USA	2000	General population	No	Online survey
Scherer et al.	Post-pilot survey	USA	45	University members	No	Online survey
Guillon et al.	Cross-sectional	France	1849	General population	Yes	Online survey
Maytin et al.	Cross-sectional	USA	513	General population	No	Online survey
Camacho-Rivera et al.	Cross-sectional	USA	10760	General population	Yes	Online survey
Benham et al.	Cross-sectional interview	Canada	50	General population	No	Interview
Blom et al.	Cross-sectional	Germany	3276	General population	Yes	Online survey
Bachtiger et al.	Cross-sectional	UK	12434	NHS users	No	Online survey
Matt et al.	Experiment	Germany	309	General population	Yes	Online survey
S. V. et al.	Text analysis	World	70212	Twitter general population	NA	Tweeepy
Thomas et al.	Cross-sectional	Australia	1500	General population	Yes	Online survey
Zhang et al.	Readability	Australia, Bahrain, Colombia, Ghana, Iceland, New Zealand, Singapore	7	NA	NA	Readability Test Tool
Abuhammad et al.	Cross-sectional	Jordan	1654	General population	No	Online survey
Suh et al.	Cross-sectional survey and interview	South Korea	506	General population	Yes	Online survey, Interview
von Wyl V et al.	Longitudinal	Switzerland	1511	General population	Yes	Online survey
Zimmermann et al.	Comparative mixed methods	Germany, Austria, Switzerland	172	General population	No	Online interview
Romero et al.	Cross-sectional	USA	25	People with a medical condition	No	Online interview
Keshet et al.	Text analysis	Israel	714 comments	NA	NA	Scraping

Table 1. (continued)

Authors	Type of study	Nation	n° of subjects	Population	Representative	Tool
S. V. et al.	Text analysis	World	5025 Reddit posts	Reddit general population	NA	PRAW [#]
Montagni et al.	Cross-sectional	France	318	Health science students	Yes	Online survey
S. V. et al.	Text analysis	India, Brazil, South Africa, Argentina and Columbia	50000 tweets	Twitter general population	NA	Scraping
Bradshaw et al.	Cross-country survey	Australia, USA	2006	General population	Yes	Online survey
Kaspar et al.	Cross-sectional	Germany	406	General population	No	Online survey
Rekanar et al.	App review analysis	Ireland	1287	NA	NA	App reviews text
Mouter et al.	Discrete choice experiment	Netherlands	926	General population	Yes	Survey
Sharma et al.	Longitudinal	India	28247	General population	No	Interview
Garrett et al.	Cross-sectional	Australia	4246	General population	Yes	Survey
Wnuk et al.	Cross-sectional	Poland	1046 + 1680	General population	Yes the first sample, no the second one	Survey
Giansanti et al.	Cross-sectional	Italy	5825	General population	No	Online survey, telephone survey
Bente et al.	App usability	Netherlands	44	General population	No	Interview and Usability test
Kawakami et al.	Prospective	Japan	902	Employed adults	No	Survey
Oldeweme et al.	Cross-sectional	Germany	1003	General population	Yes	Survey
Munzert et al.	Hybrid	Germany	2527	General population	Yes	App data and Survey
Horstmann et al.	Cross-sectional	Germany	1972	General population	No	App data and Survey
Garrett et al.	Cross-sectional	Taiwan	957	Young adults 18-25	No	Survey

[#] NA = Not Applicable; ^{*} PRAW = Python Reddit API Wrapper

Table 2. Benchmark summarization

Benchmark	Definition
Knowledge of the technology	Awareness of the existence of the technology and its tools (eg, smartphones)
Willingness to download	intention to effectively download the app on the device
Accessibility of the technology	Barriers to access (eg, dated smartphone, digital divide)
Download percentages	Actual download numbers
Adherence/compliance to the technology	Continuous and appropriate app usage
Self-efficacy and community empowerment	Self-oriented and altruistic actions to favor public health
User profiling	Characteristics of people using the app
Privacy	Who owns the data and how this data is used
Government trust/surveillance	Feelings towards the government in regards to gathered data
Cybersecurity	Data security dimension and its perception
Social media sentiment	Comments on social media regarding DCT
Communication	How governments, institutions and agencies communicate DCT technology, boundaries, benefits and dangers
Feedback & improvements	Userbase suggestions to improve DCT app experience
Usefulness	The raw usefulness dimension as perceived by the population

We found a pool of 7 studies from Europe, Australia and India reporting at least one percentage number of downloading a DCT app among the general population (12,19–24).

4 records were declined as positive with download percentages ranging from 37.3% (21) to 87% (12). On the other hand, 5 records were declined as negative, with percentages of missed or refused downloads ranging from 27.7% (21) to 94.8% (22).

Among neutral records, Munzert and colleagues also identified a 6 weeks range time after which app adoption levels plateaued (24).

As for specific populations, we found 2 records, classified as negative, indicating low downloading percentages at 11.3% of French healthcare students (10) and 20.4% of Japanese employed adults (25).

5. Adherence/compliance to the technology

Given that downloading is a crucial starting point, DCT effectiveness is premised both on continuous and appropriate app usage. These two concepts are summarized by the endpoints of adherence and compliance, grouped under one unique outcome.

As for the general population, positive and negative records were quite balanced, both in terms of

percentage data and of motivational framework data behind the scene, as well. According to Abuhammad and colleagues, in Jordan, only 37.80% were current users of a DCT app (26). On the other hand, Garrett and colleagues found that in Australia, with real-world tracking scenarios, Bluetooth usage was 71% “at all times” and 89% “when in public” (12).

From the analysis of the driving psychological promoters of continuance intention, anticipation, arousal, flow and hope proved to be highly meaningful. Discontinuation counterparts were anger, dissatisfaction, disappointment, annoyance, frustration and disgust. According to S.V. and colleagues, when looking at developing countries, those with a positive outlook of DCT kept doing so, whereas those with a negative outlook on DCT progressively fed on the neutral quota (27).

Referring to a specific population, Montagni and colleagues reported that 4,7% of French healthcare students were still using the app after downloading it, that is less than a half of those who had downloaded it (11.3%) (10).

6. Self-efficacy and community empowerment

Adherence and compliance are influenced by many factors. In this respect, self-efficacy is the most

directly linked one. The self-efficacy concept contains that of the so-called “Health Belief Model” (HBM), but with a wider perspective, embracing the dimension of community empowerment. It is part of its natural evolution at a community level. HBM was born in the 1950s, conceived by social scientists at the U.S. Public Health Service to explain the psychological and behavioral mechanisms leading to the adoption of disease prevention strategies (28). The same drivers were further meant to predict patients’ compliance with medical treatments. In order to predict the likelihood of adoption of a recommended health behavior, this model balances one’s belief in the sense of personal threat posed by a disease condition, with one’s trust in the safety and efficacy of the implied recommended measure (29). Psychologist Albert Bandura defined self-efficacy as a person’s belief in his ability to succeed in specific settings or complete a task as part of his social cognitive theory.

If the HBM deals with one person’s perception of the benefits and barriers associated with certain health treatment, action or measure, so does self-efficacy, yet getting deeper in the idea of the entirety and of the continuum of a person in every share of life that influences one’s own health and well-being. Self-efficacy sets the stage for people’s choices and self-determination. Since every person is in constant relationship with others, individual self-efficacy translates into that of an entire society, resulting in what is better defined as “community empowerment”, or making good use of its resources to adequately address needs and aspirations.

There are various data about self-efficacy and community empowerment regarding the general population, highlighting the role of this dimension in the acceptance of DCT. 9 authors dwelled on considering this aspect in their papers. We selected 12 records, equally declined into positive and negative. Referring to percentages, according to Altmann and colleagues, 68% of the multi-country poll for France, Germany, Italy, UK, and USA, downloaded the app to protect family and friends (F&F) (30). Horstmann and colleagues found similar percentages in Germany, since 65.06% stated that benefits outweigh risks, 66.53% believed that the app would stop the pandemic (20). On the other hand, being doubtful about the app

contribution to the pandemic containment (29.22%) was among the main reasons for not downloading the app. In another study by von Wyl V and colleagues, in Switzerland, lack of perceived benefit (36%) was found as the first main reason for not using a DCT app (17). Mouter and colleagues, in the Netherlands, stated that 64.8% weighted privacy and freedom above all else when choosing a DCT app, regardless of avoided deaths (23).

Focusing on the other narrative results, it emerged that DCT supporters considered it essential to protect other people and weighted positive effects more than privacy and surveillance concerns; perceived threat and lack of personal control were significantly positively related to DCT technology acceptance; higher uptake was identified in people perceiving COVID-19 as personal or F&F threat, those living in outbreak areas, those using public transportation, those visiting F&F, those visiting restaurants and bars once a week or less, those trusting healthcare system and science in general. On the other hand, uptake was lower in people with lower NPI (non-pharmacologic interventions, like social distancing and mask wearing) compliance and young, as well as less future-oriented people were less willing to use a DCT app. In Germany, according to Oldeweme and colleagues, using a DCT app reduced perceived performance and privacy risks but not social risks and COVID-19 concerns (31).

In terms of specific populations, Kawakami and colleagues revealed that downloading a DCT app decreased general psychological distress of Japanese employees although not COVID-19 specific worry. It was not possible to replicate the findings of general psychological distress reduction when using severe psychological distress as an indicator of poor mental health (25).

7. User profiling

Considering self-efficacy, we have started outlining a characterization of people more inclined to accept and download a DCT app.

In addition, other various socio-demographic features were examined throughout the papers.

Regarding the general population, 11 papers identified different DCT app users’ profiling characteristics.

We selected 18 appropriate records, 8 of which declined as positive (15,17,20,22,24,26,32,33), 8 as negative (15,17,20,33–37), 2 as neutral (15,33).

Overall, increased likelihood of acceptance and app uptake was associated with higher income, richer area of living, higher education, authority trust, more frequent internet use, coping skills as well as pandemic suppression measures support such as better mask adherence, at-risk groups. Referring to age, there was not a common line among the different studies. According to Munzert and colleagues, German uptake was more prevalent in older (50+ years) than younger (18–49 years) adults (24). Camacho-Rivera and colleagues found a similar result in the USA, identifying people ≥ 60 years old as significantly more likely to use mHealth tools, basically mobile and wireless technologies to assist the achievement of health objectives (38), to fight the pandemic (32). On the other hand, the Italian study of Giansanti and colleagues found that young people were more familiar with “Immuni” (the Italian DCT app) than elderlies (15).

For what regards gender, both according to Horstmann and colleagues. and to Zhang and colleagues, it resulted that females were less supportive than men (20,34,35). Political differences between users and non-users were mainly imputable to authoritarianism versus stronger endorsement of liberty.

No data were available about specific populations.

8. Privacy

Beyond accessibility and individual characteristics conditioning a certain predisposition to DCT, some main concerns represent the common thread of all the barriers examined by the different authors. In fact, concerns were mainly reported in terms of privacy, government trust/surveillance and cybersecurity.

A total of 8 articles were discussing the privacy concerns: 6 for the general population and 2 for the specific populations. Of those discussing general populations, 2 papers expressed positive views (18,31) and 4 expressed negative views (17,20,39,40). Regarding the positives, Rekanar and colleagues found that 60.9% of users were satisfied and even praised the transparency efforts of the Irish DCT app (18). Moreover, as found by Oldeweme and colleagues, by using

a DCT app, citizens are inclined to review and curb their criticism in regards to privacy and performance risk perception (31). On the other hand, when looking at the negatives, Horstmann and colleagues and von Wyl V and colleagues agree on privacy being one of the top three reasons for not downloading a DCT app (17,20). Indeed, privacy concerns are thought to outweigh societal benefits (39) and the ownership of the collected data is questioned in terms of security and legal validity (40).

For what concerns specific populations, the study of Romero and Young highlights the following positives about privacy in a random USA sample: i) 76.9% of those who refused to share data, would agree to share location data if it were for COVID-19 only; ii) 46.2% of those who were against sharing data would revise their decision depending on further elaboration on research purpose; iii) 32% were open to disclose private information to advance public health research (41). The work of Garrett and colleagues, highlights the following in a young Taiwanese sample: i) sunset clause requirement (meaning an expiry date for collected data) and ii) local storage option for data would boost acceptance by making the system feel more privacy-preserving. Also, the Apple and Google tracking system is perceived as a riskier option than a government infrastructure for data collection (14).

9. Government trust/surveillance

The idea of public health is tightly linked to the perception and trust towards the government. In fact, government trust or government surveillance is a rich topic and fundamentally different than privacy. If privacy is a core right of many constitutions worldwide, the government perception (trust if positive or surveillance with a more negative undertone) is enacted by both citizens and the state itself. In the general population context, a total of 8 articles were found discussing government trust/surveillance. Four of which declined as positive (23,35,42,43) and 4 as negative (30,40,44,45). On the positive side, Zhang and colleagues found that 42% support government-backed DCT app download and usage (35). Bradshaw and colleagues report that, in Australia, government legitimacy strongly correlates with a positive DCT

app perception (42). Similarly, Mouter and colleagues report that government trust synergizes with the DCT app download rate (23). Also, Bente and colleagues, in the Netherlands, elaborate that DCT app reliability may be tied to sufficiently high government trust levels (43). On the negative side, Altmann and colleagues report that 42% are worried about government surveillance through the future use of DCT app infrastructure (30). S.V. and colleagues showcase through social media text-analyses, the concerns of continuous surveillance, spying and general safety risk from the public scrutiny (40,44). Keshet and colleagues report even a stronger sentiment with DCT technology as a violation of human rights (45).

No data was available for specific populations.

10. Cybersecurity

Cybersecurity is the practice of protecting critical systems and sensitive information from digital attacks (46). The concept is deeply intertwined with privacy and it is especially relevant when discussing a new infrastructure, developed at “pandemic speed”, with data that matters for those who agree to share. Possibly it is even more relevant for those who do not share data and may be intimidated by the dangers of acquiring, storing and analyzing public health data. We have identified 6 articles for the general population and 1 article for the specific populations. For the general population, 4 articles highlighted positive views on DCT cybersecurity (18,22,30,43), whilst 3 articles highlighted negative points (14,22,42). When discussing the positives, Kaspar and colleagues found that, among German-speaking people, well-trusted use, management and protection of data, when properly disclosed, bolster motivation to use a DCT app and even provide additional data such as infection status (22). Also, Rekanar and colleagues found that 72.8% were expressing positive comments on the data protection (18), almost complementary with the findings of Altmann and colleagues that found 35% being worried about cybersecurity (30). A peculiar positive is noted by Bente and colleagues, in which the sample considers Bluetooth technology to be safer for the acquisition and storage of data (43). For what regards the negatives, Bradshaw and colleagues’ findings highlight how

poor information safety decreases intention to download and recommend a DCT app to F&F (42). In addition, Kaspar and colleagues found that perceived vulnerability to data misuse is negatively correlated with participants’ willingness to share additional data such as infection status (22).

For what regards the specific population paper by Romero and colleagues, the random sample had negative views on cybersecurity as 40% with concerns on data collection, 28% feared selling data for profit, 24% had confidentiality and security concerns, 8% worried regarding the type of collected data and the possibility of the data being used against them (41).

11. Social media sentiment

Social media is the core of modern communication. It is only natural for scientists to scope modern, text-based agoras to poll the specific populations of each platform. Each social has its unique demographics. Plus, barriers to access for geographic limitations, smartphone or data connection make it even harder to generalize. Stil, Twitter and Reddit (the two platforms of interest in our case) do represent a vocal, engaged part of the worldwide community, making the following data very relevant. The two papers are from the same group of S.V. and colleagues and express views spanning across the whole spectrum (positive, negative and neutral) (40,44). Regarding the positives, 33.9% of tweets had positive sentiments towards DCT (44). In regards to Reddit, positive sentiments accounted for 29.9% of the analyzed text (40). For what concerns the negatives, 12.8% of tweets had negative sentiments towards DCT (44) and 20.8% of Reddit-analyzed text expressed negative views on DCT (40). Regarding neutral sentiments, indifferent sentiments were 53.7% of tweets and 49.17% of Reddit-analyzed text.

12. Communication

The communication domain covers how public health agencies, government and private entities communicate to the public regarding DCT apps. Regarding the general population, we have included 5 papers, 2 with positive declinations (31,47), 2 with negative ones (11,43) and 1 with a neutral tone (42). For the

positives, Benham, Oldeweme and colleagues show how positive framing bolsters app acceptance (47) and transparent communication fights government distrust (31). For the negatives, Zimmermann, Bente and colleagues show that insufficient knowledge of deployed technologies and lack of clarity when communicating simplified working mechanisms, affect citizens' willingness to use DCT apps (11,43). Of notice how older adults and lower-educated youth share the same technological illiteracy (43). Regarding the neutral declination, Bradshaw and colleagues find that F&F recommendations and intention to download are not susceptible to framing changes if information safety is state and guaranteed upfront (42).

For the specific populations, Bachtiger and colleagues' study on UK NHS users find that more understanding of government rules about DCT apps may boost DCT uptake by at least 30% (13).

13. Feedback & improvements

Some authors have also scoped a peculiar dimension: proactive feedback of the userbase. This category highlights how to potentiate certain DCT app features or comment on poor execution or behavior of existing ones. For the general population, we have found 4 papers for this topic. For the positives, 2 papers have been included (37,39). For the negatives, 1 paper (18). For the neutral, 1 paper (35). In regards to proactive suggestions: Maytin and colleagues show that, in the USA, 33.4% were willing to background location sharing and 42.1% were willing to input additional data (37). Matt and colleagues also found that German users would be incentivized to adopt a DCT app if they were involved in the design process (39). Regarding the negatives, Rekanar and colleagues found that 91.51% of people expressed negative comments on application performance and 66.66% expressed negative comments on the user experience (18). A neutral view is shown by Zhang and colleagues in which 57% of polled people support classical CT expansion.

For what regards specific populations, the paper by Scherr and colleagues on Vanderbilt University campus, shows that user experience is key for acceptance and web-based interfaces are more disliked than native apps (48).

14. Usefulness

The usefulness is a benchmark by itself because it is logically linked to the acceptance parameter. It is a dimension only scoped by a single article, for the Spanish general population. Rodriguez and colleagues found that 82% reported the app being useful (49).

Conclusions

The goal of this systematic review is to comprehensively appraise what works in favor of DCT acceptance by narratively weighing 14 benchmarks. Limitations of this review recall the very eclectic nature of the acceptance dimension itself, as well as the heterogeneous diffusion of DCT apps all over the globe, which did not allow us to stick to a mere quantitative analysis. Ideally, every single benchmark should have been reported by each author in an easy comparable form, while different studies often focused on different aspects, only when feasible reporting percentages of data. Accessibility, communication, privacy, cybersecurity and self-efficacy are the cornerstone of a successful policy. An actionable strategy would look both at the available user base and at non-users. Regarding users, early data shows two groups: early adopters, in general living in urban areas, with higher household income, with more frequent public transport use; and late adopters, usually part of disadvantaged, more fragile communities. Early adopters display pro-socialness traits (eg, altruism, self-efficacy), higher COVID-19 risk perception and more technological fluency (50). For them, the cornerstones are already valid enough. Late adopters, on the other hand, are incidentally those that would need the most protection but often lack equipment (20,51,52) and understanding of technology (43) Interventions are speculative but transparent communication, education-level-adjusted (34), aimed at explaining the technology and the boundaries on data usage is fundamental (12). Also, in the future basic technological literacy will be a prerequisite for healthcare, regardless of pandemic mitigation measures. Digital health technologies have the capacity to bring healthcare services to everyone (53,54), helping those more vulnerable to feel safe, meaningfully helped

while also contributing to public health. Meeting earlier the 20% (4) uptake threshold would positively contribute to pandemic control and potentially break the vicious cycle of small app diffusion numbers that negatively affect DCT standing in the eyes of public opinion.

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