Never ever or no matter what: Investigating Adoption Intentions and Misconceptions about the Corona-Warn-App in Germany

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Abstract

To help tackle the COVID-19 pandemic, the tech community has put forward proximity detection apps to help warn people who might have been exposed to the coronavirus. The privacy implications of such apps have been discussed both in academic circles and the general population. The discussion in Germany focused on the trade-off between a centralized or decentralized approach for data collection and processing and their implications. Specifically, privacy dominated the public debate about the proposed "Corona-Warn-App." This paper presents a study with a quota sample of the German population ($n = 744$) to assess what the population knew about the soon-to-be-released app and their willingness to use it. We also presented participants potential properties the app could have and asked them how these would affect their usage intention. Based on our findings, we discuss our participants' views on privacy and functionality, including their perception of selected centralized and decentralized features. We also examine a wide range of false beliefs and information that was not communicated successfully. Especially technical details, such as that the app would use Bluetooth, as opposed to location services, were unknown to many participants. Our results give insights on the complicated relationship of trust in the government and public communication on the population's willingness to adopt the app.

1 Introduction

Since the spread of COVID-19 in 2020, governments have been developing measures to fight its transmission. One of these measures is the use of contact tracing apps. Early in 2020, the public media in Germany discussed two different approaches. The *centralized app* was based on PEPP-PT [24], while the *decentralized app*, was based on DP-3T [44]. Both approaches come with advantages and disadvantages. The public debate was driven by researchers who signed an open letter (April 2020) backing the decentralized approach [7], as well as privacy advocates (April 2020) [11]. A major argument was that the general population would only be willing to adopt the app in sufficient numbers if privacy was preserved [7]. The German government had previously committed to the centralized app, which they abandoned during development due to the public debate, starting a new development project based on the decentralized approach at the end of April. The media extensively discussed this decision, and the government, via direct appeals and public media, encouraged people to install the app. In this context, we were interested in finding out how much the general public understood about the newly announced but, at the time of conducting the study, yet to be released decentralized app. We were also interested in the general public's attitudes towards potential properties, particularly those about the centralized and decentralized approaches' advantages and disadvantages. To gain insights into these issues, we conducted an online survey study from May 30 to June 11, 2020, with a quota sample of 744 participants from Germany. The app was released on June 16 and became one of the most installed European apps [43].

In this paper, we make the following contributions:

- We conducted the first study to assess participants' knowledge of and beliefs about the planned Corona-Warn-App (CWA) after the app features were published and broadly discussed in the media. This is in contrast to other studies in Germany that focused on hypothetical apps.

- We assess *how accurately* participants could identify the properties of the planned German contact tracing app.

- The German public discourse was dominated by the discussion of a centralized versus decentralized application.

We offer insights into the level of relevance of the app's capabilities linked to the centralized approach.

- We compare our work to contemporary work that assessed willingness to install various hypothetical tracing apps in Germany [68].

2 Related Work

In this section, we discuss related work in three areas relevant to the context of this work. 1) The discussion about technical aspects of tracing apps and their history/development in Germany, in particular between the centralized and decentralized approach; 2) studies about the acceptance of contract tracing apps and influence of factors in released or hypothetical corona tracing apps. 3) Research on the existing knowledge of users about upcoming or already released corona tracing apps.

We note that most of the literature was published after we designed and conducted our study, so we compare our results retrospectively.

2.1 Technical background/history

The idea of supporting contact tracing with mobile apps emerged early in the pandemic. The first working app to fight COVID-19 was released in March 2020 in Singapore [21], only two months after the first reported infections outside of China [35]. The app had the disadvantage that it had to be constantly the visible app on the smartphone to allow data exchange. For such an app to effectively support health agencies in contact tracing, a large set of the population has to use it, depending on the overall scenario (e.g., how quarantine is handled) [55].

In Germany, two approaches to collect and process the data were discussed. In the centralized version called "Pan-European Privacy-Preserving Proximity Tracing" (PEPP-PT) [24] all collected encounters, namely contact-ID and timestamp of encounters with other app users would be uploaded and stored on a central server. In the decentralized version "Decentralised Privacy-Preserving Proximity Tracing" (DP-3T) [44], all encounters remain on the users' smartphone. If a user tests positive for COVID-19, they can upload all their cryptographic keys (from which the IDs can be derived) to a server. Once a day, a list with keys of people who reported their positive COVID-19 tests is downloaded to all users' smartphones and compared to locally stored encounters within the last 14 days. The important difference is that determining whether a user has been at risk of contracting COVID-19 is calculated on their smartphone itself and the encounter data never leaves the phone. At the beginning of the discussion, the German government wanted to follow the centralized approach [25]. After two open letters in April 2020 suggesting the usage of DP-3T [7, 23], the German government changed course and pivoted to the decentralized

approach on April 26 [12]. Two days later, a press release was published that contained (technical) information about the app, such as that it would work with Bluetooth [27].

2.2 User acceptance of tracing-apps

Since the idea to use apps that would support the contact tracing work of the health departments to contain COVID-19 became popular among governments worldwide, researchers aimed at understanding user preferences to allow for broad adoption. Studies were conducted in Australia [66], Europe [65] (including Belgium [70], France [45, 52], Germany [45, 48, 56, 59, 60, 67, 68], Italy [45], Ireland [63], Switzerland [69] and the UK [45, 46, 57, 71, 72]) and the USA [41, 45, 51, 53, 54, 58, 59, 61, 62, 64, 65, 68, 73]. As Utz et al. [68] and Kostka et al. [59] found similarities for Europe and America, we focus on work conducted with those populations.

Most conducted studies were choice-based conjoint experiments, in which participants were asked to select which app of several they would prefer or were given different app configurations for which they had to decide if they would install such an app [48, 68, 71, 73]. Some studies asked to imagine a corona tracing app has already been released [45, 54, 57, 59, 61, 70] We are aware of only a few studies that looked at the user acceptance and influencing factors on the acceptance for the app that was already launched in the surveyed country [66, 69].

Investigated Factors The studies explored factors that could influence participants' intention to install and use the corona tracing app. Several authors investigated how personal characteristics, such as demographics or one's experience with the pandemic, impacted the acceptance of corona tracing apps [45, 46, 48, 52–54, 56, 59, 61, 68, 69, 73]. Amongst others, people who were male [56, 61, 68], had higher trust in the respondent's government [45, 48, 52, 68, 69], health authorities [69] and others in general [56], had higher income [61, 69] or lived in urban areas [59, 61] were more likely to install a tracing app. While some authors noted that younger participants were more inclined to use a tracing app [53, 56, 61], others found the opposite [54, 59]. Looking at pandemic-related factors, health concerns during the pandemic, and personal experience with COVID-19 increased the willingness to install a tracing app [48, 52, 53, 59, 68]. Additionally, better adherence to COVID-19 regulations was a positive influence [69]. Fear and anxiety concerning changes in government rules [46] impacted participants negatively.

Apart from factors that might influence the acceptance of contact tracing apps in general, many studies were conducted to find which app design choices would be considered positively or negatively by participants. The studies covered different attributes (e.g. what data will be collected) [48, 58, 61, 62, 73], the apps purpose [68] or what institution will develop, host, distribute or own the app [41, 48, 53, 57, 64, 65, 71]. Li et al. [62] found a preference

for the centralized, while Zhang et al. [73] had more participants who were willing to use a decentralized app. Horvath et al. [57] found a centralized national health system to be favored. Participants rated health agencies more trustworthy than their government as a whole concerning corona tracing apps [57, 65]. Still, Simko et al. [65] found no entity that everyone trusted. Anonymous data collection impacted participants positively in their decision to use an app [48] and it was perceived negatively if the collected data can uniquely identify individuals [68]. Independent of app design choices, studies often found a subset of participants who did not like any of the proposed apps [58, 62, 68].

Aside from app properties, researchers looked into effects an app could have, and the influence this has on adoption [48, 61, 71] such as malfunctions of the app [58, 68] or the perceived effectiveness in fighting against COVID-19 [59–61, 70]. They found that participants' perception of the (public) health benefits an app would offer and other people's willingness to use it explained the usage intention better than app design choices and personal characteristics [61]. Performance expectancy and the benefit were also among the most critical predictors in other studies [59, 60, 70]. Malfunction in contact tracing was found to be of negative influence [68] and participants valued false negatives worse than false positives [58]. The willingness to use contact tracing apps increased if its usage is linked to priority testing [48, 71]

Further, numerous studies identified the primary reason why users would or would not install tracing apps [45, 46, 56, 63, 66, 68, 69, 72]. In their studies, privacy concerns [45, 46, 56, 66, 68, 69, 72], technical concerns or lack of technical equipment [56, 66, 69], distrust in the government [66] or the fear of surveillance at the end of the pandemic [45, 63] and doubts about the effectiveness or benefit [56, 69] were brought up as negative influences. The following topics were mentioned as reasons for using a tracing app: willingness to protect family and friends [45, 63], a sense of responsibility for the community [45, 63, 72] and the hope that the app may stop the pandemic [45].

2.3 Knowledge about corona tracing apps

The subsequent studies examined what participants knew about corona tracing apps apart from factors and properties influencing users' installation or usage intention. Simko et al. [65] conducted surveys for seven months in the US and Europe, focusing on contact tracing and privacy and asking for potential app properties. Within the participants' answers, they identified several false mental models, e.g., that proximity tracing is less secure than location tracking due to constant communication between devices. Zhang et al. [73] surveyed 2000 participants in the USA to measure the support for nine different COVID-19 surveillance measures, including tracing apps. While analyzing, they noticed participants had many misunderstandings about the described app, although the de-

scription was still visible when they answered the questions. For example, a third believed they would receive the names of infected people they had been in contact with. The number of incorrect answers could not predict the participants' usage intention. Williams et al. [72] conducted focus groups in the UK to explore public attitudes to the proposed contact tracing app. The authors found the most common misconception was that the app would make it possible to precisely identify COVID-19 cases in their vicinity and amongst their contacts. In one study that took place outside Europe and America, Thomas et al. [66] surveyed 1500 Australians after the national tracing app was released and examined participants' knowledge about it. Around 70% knew the app would make it easier and faster to inform people exposed to COVID-19 and warn users who would not have been warned otherwise. However, 50% did not reject the assumption that their personal information would be used after the pandemic, and 57.4% believed the app would warn if infected people were near them.

3 Methodology

This section describes instrument development and the conducted survey, our recruitment, and the data analysis process.

3.1 Survey Development

We followed the public discussion of the CWA. We were interested in the information that potential users have, mainly as discussions focused on whether enough people would install it and why (not). Much of this discussion in Germany revolved around the topic "centralized versus decentralized" and the claim that this would heavily influence the willingness to install. As there was little concrete related work on users' perception, we were also interested in the broader topic of acceptance and beliefs. We discussed factors and potential influences with other researchers and iterated multiple times over the survey.

Pre-Testing Before handing out the survey, we conducted several test rounds with colleagues who were not involved in the survey creation to identify comprehension problems. Following that, we asked 19 computer science students to fill the survey and provide additional feedback about unclear sections and inconsistencies. After this, we additionally sampled 50 participants on Clickworker [6]. Finally, we asked five participants without a technical background to fill the survey while thinking aloud. Before starting the final study, Qualtrics [29] additionally sampled 50 people. This pilot study helped get an overview of the duration, evaluate the randomization and spot flaws in the survey logic.

3.2 Survey Content

To inform the survey structure and questions, we looked at the different available approaches to develop a contact tracing

app and followed the media discussion. The final survey consisted of the following described four parts and can be seen in Appendix A.

Media Sources and Knowledge   In the first part, we asked whether the participants had already heard of the planned app and asked for their knowledge sources (e.g., public broadcasters, family members, social media, or official government websites) (Q7). After this, we asked questions that assess their knowledge of the properties of the app in general (Q8). We also asked such questions for two scenarios: what happens if other users are infected (Q9) or if the users themselves are infected (Q10). In these three question blocks, we included 23 statements that were either correct (8 statements) or incorrect concerning the soon-to-be-released app (15 statements). As incorrect statements, we used properties of another 'corona app' released in Germany [8][1] or were discussed in media at the time of the survey. For example, we included the misconception that the app will share all phone numbers saved on the user's phone or share a movement profile with the government. Three statements were neither correct nor incorrect for the released app. Details of all these statements can be found in Table 6.

Disposition to use   In the second part of the survey, we showed the participants a minimal description of the app, including the information that its primary purpose will be to warn users who have been close to infected persons and use Bluetooth to detect other app-users. Following that, the participants were asked whether they are planning to use the app, using a question with five possible answers ranging from "1 - Definitely will use it" to "5 - Definitely will not use it" (Q12). We also asked to report their primary reason for their choice in a text field (Q13).

Potential Properties   The third part presented 23 hypothetical statements, from now on called *potential properties*, about the app (Q14). The participants were asked how these statements would affect their willingness to use the app if the app would work this way (5 answer options, from "1 - Definitely would use it" to "5 - Definitely would not use it"). In this section, we added an attention check question. Six of those properties can be attributed to a centralized approach, while one would only be valid for the CWA app that is based on the decentralized approach. Additionally, 12 properties were correct for the to-be-released app, while 11 were incorrect. Details of all the presented statements can be seen in Table 7.

Demographics   In the end, we asked for demographic data and how COVID-19 impacted their lives (Q16-29).

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[1]The app can be used to share fitness data with the RKI.

3.3   Recruitment

We used Qualtrics [29] to recruit a representative German sample according to age, education, household income, and federal state/region. Qualtrics provided representative numbers for age, education, and region, numbers for income were taken from the Federal Statistical Office of Germany from 2017 [17]. Due to the nature of online surveys, older participants were underrepresented, and we could not entirely fulfill our quotas for a representative sample. The final distribution after sanitizing the data together with our targeted quotas can be seen in Table 1. The study was conducted from May 30 to June 11; thus, shortly before the app was launched on June 16, 2020. To take part in the study, it was required that the participants owned a smartphone since that is a precondition to use the app. 1025 participants took part in the study for which we paid Qualtrics €4000.

3.4   Data quality

During the study, Qualtrics excluded participants that 1) took less than half the median of the time the participants needed in the final pilot study (243 seconds) for completing the survey, [2] or 2) failed the attention check question in the potential properties question block.

To ensure our participants were paying attention, we included a straightforward attention check (Q14) and one comprehension check question (Q11). The comprehension check question gave a short explanation of how the app will work (specifically mentioning using Bluetooth for contact tracing). It then asked what technology the app will utilize for contact tracing. We excluded participants from our analysis who did not choose "Bluetooth".

When we designed this question, it seemed quite straightforward. To our surprise 262 participants failed this question. We then discussed whether we had overlooked genuine reasons why this question might be answered incorrectly. Potentially, participants who read our description text did not believe it and answered true to their previous or internal beliefs. It is also possible that our description was too complex for some to understand and thus could mean that they misunderstood other questions.

We also discussed the possibility of excluding participants due to inconsistent or odd answers, e.g., a participant stating that they are a civil servant but also stating that they lost their job[3] or stating that the app used Bluetooth in one question and stating otherwise in another. However, after an in-depth discussion, we decided against this. We looked at the free text answers of participants who had such inconsistencies, but we found them generally to be as plausible as those who did not and did not find any other warning markers.

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[2]This is a standard procedure at Qualtrics; we do not know how many participants were excluded.

[3]In Germany this combination is incredibly rare

3.5 Analysis

We analyzed the data in two different ways. Most of the results concern a quantitative analysis of the answers. One free text answer was analyzed qualitatively. Percentages are reported rounded.

Quantitative For our quantitative evaluation, besides reporting, we performed an ordered logit regression with model selection, an ordered logit regression model containing all potential properties, and hypothesis testing. For the app usage intention, we decided to combine participants who answered "I don't know" and those who answered "I am undecided".

In the *Media Sources and Knowledge*-section (Q8-10) of the survey, we asked participants whether they thought the presented statements were correct for the CWA. False statements required no click from the participant to give the correct answer. This may influence the measured correctness of their beliefs, besides the point that some statements may be easier or harder to know. We, therefore, only report true statements that were known as (positive) knowledge and false statements that were clicked as false beliefs.

Coding process Participants were asked to indicate their primary reason for wanting to use or not use the CWA (Q13). One researcher looked at the answers and coded them according to the participant's misconceptions. All presented quotes were discussed and agreed upon by two researchers. All quotes were originally in German and translated into English by the authors.

Regressions For our exploratory regression model, we conduct a model selection approach by computing a set of candidate models based on different factor combinations, and selecting the final model based on a combination of the best Akaike Information Criterion (AIC) [49] and Bayesian Information Criterion (BIC) [1]. Possible factor categories and corresponding baselines are reported in Table 5.

Our final ordered logit regression (cf. Table 3) reports change as log odds to highlight trends: a negative value directly correlates to a negative effect and vice versa for positive values. In addition, we report a 95% confidence interval (C.I.) and a *p*-value. For convenience, we highlight factors below an arbitrary significance cut-off of 0.05 with an asterisk (∗).

In addition, to investigate potential effects of different app features, we conducted an ordered logit regression (cf. Table 4) with all app features as factors.

3.6 Ethics

Our study was reviewed and approved by our institution's Research Ethics Board. We also adhered to the German data protection laws and the GDPR in the EU. For all answers, we provided an option for participants not wanting to give any details (i.e., "I don't want to state" or "I don't know").

Participants could drop out at any time. Participants had to consent to take part.

3.7 Limitations

We aimed for a representative sample of the German population. Unfortunately, some groups are over- while others are underrepresented. Our sample lacks people of older age, people with lower education, and those with high income. Qualtrics, who acquired the sample for us, stated that this is very common in online surveys. As with every survey study, we have to take into consideration that the data is self-reported. In this study, we additionally asked participants about their future behavior, which is even more prone to uncertainty. Many possible properties of the app have consequences that are not easy to estimate. We cannot assume that participants understood and thought of the consequences, especially considering many participants did not understand how the app worked in detail.

4 Results

In this section, we present the results of the survey. We describe our participants, the accuracy of their knowledge about the CWA, and what sources they consulted. Following that, we describe the participants' intention to use the app and how demographic factors and beliefs about the app explain this decision. Last, we describe how different potential properties, such as additional features, influence the willingness to install the app.

To avoid confusing and overly complicated figures, we assigned short identifiers to each question, which can be seen in Table 6 and Table 7.

4.1 Demographics

Table 1 presents the demographics of the final 744 participants and Table 8 gives an overview of how COVID-19 impacted them.

Since we conducted the study at an early stage of the pandemic, few participants had fallen ill with COVID-19 themselves or had somebody close to them fallen sick. 31.1% count themselves as being a member of the high-risk group. This may seem high but matches estimations in Germany [30]. Around half reported that the pandemic did not influence their work situation (52.7%). 24.5% work from home, and 13.6% reported working in short-time. 74.9% said they did not have specialized tech skills. According to the "Sonntagsfrage" [42],[4] our sample includes 20.7% fewer participants who would have voted for the CDU/CSU[5] at the time the survey was conducted, but 6.6% more participants who would

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[4]Regular opinion research in Germany, asking, "Which party would you vote for if federal elections were held this Sunday?"

[5]The Christian Democratic Union of Germany / Christian Social Union in Bavaria

vote for The Greens. All other parties are close to the percentages of the "Sonntagsfrage". We hypothesized the party preference might be an indicator of the attitude towards the app as at least one party publicly criticized the app [33].

4.2 Knowledge

We asked participants to select what they believe are correct statements about the app (Q8-10). As the app was not released when the survey was conducted, answers were not based on experience with the app. However, a press release had been publicized that gave information about the app [27], such as that it would use Bluetooth-Low-Energy, that its primary purpose would be to warn users who had been in close contact with infected people, and that users would not learn who of their contacts reported an infection. At the same time, much misinformation about the app, its purpose, and technical details were spread as well [5].

This section describes the sources participants used and presents participants' beliefs about the to-be-released CWA.

Sources We asked the participants whether and where they heard about the planned corona app (Q7). Figure 3 shows the frequency of how often the participants reported a source. Please note that as participants could report more than one source, the percentages do not add up to 100%. Few but a non-negligible amount of participants (11.7%) reported to never have heard of the app. This leaves 657 participants who were at least somehow aware of the app.

More than half of the participants (54.7%) reported that they received information about the app from public broadcasters. The second most common marked source was social media (29.6%), such as Twitter or Facebook.[6] Scientific publications were used by 7.9% to get information about the CWA.

Correctness of assumptions The following paragraph gives an overview of the participants' assumptions about the CWA (Q8-10). It should be noted that we only included participants who previously reported that they already heard about the app (n=657).

Figure 4 depicts the correct statements for the app that was shortly released after the survey was conducted and shows how many participants marked those to be true. Figure 5 shows all statements that are false for the released app. We classified participants who marked any of the false statements as correct as having "False Beliefs".

59.5% of the participants knew about the app's basic functionality, i.e., that it would warn its users when they had been in contact with another user who later tested positive ((OTH) INFORMS IF CONTACTED INFECTED and (SLF) INFORMS MY CONTACTS). Around half of the participants knew about the detailed flow that a lab has to confirm the infection before

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[6]Following a statistic from Statista, 65% of the citizens use social media in Germany in general [2].

it can be registered in the app ((SLF) DATA TRANSMISSION ONLY AFTER CONFIRMATION) to prevent misuse of the app and many false warnings.

However, the app's technical basis was less known: Only 29.8% of the participants who reported to have heard about the app knew that the app would share temporary IDs and timestamps, and 43.5% were aware the app would use Bluetooth. At the same time, 54.6% of the participants thought that the app would use location services, and 24.7% believed the app would use Bluetooth and location services in combination. Although Bluetooth is not a technique developed for position finding, it is, next to GPS, listed as a "location service" in some circumstances [3]. We assume that only participants who marked Bluetooth and location service could have been aware of this detail. 30.0% did not think the app would use Bluetooth but checked location services.

A common misconception (57.5%) was that the app would warn users if an infected person is in their vicinity.

9.89 % of the participants knew all the information that was included in the official press release about the app ((GEN) SHARES TEMPORARY IDS, (GEN) DETECTS NEARBY USERS, (GEN) USES BLUETOOTH,   (GEN) FIGHTS DISEASE SPREAD,   (OTH) INFORMS IF CONTACTED INFECTED, (SLF) INFORMS MY CONTACTS [27]).

On average, the participants correctly recognized around half of the eight aspects that are true for the app ($median = 4, mean = 4.26, std = 2.05$), but none was known to everyone. Only five participants marked all correct attributes as such and did not believe any incorrect statement.

We asked for the classification of two statements ((GEN) RESTRICTS BASIC RIGHTS,   (GEN) THREATS PRIVACY) that cannot be classified as correct or incorrect but are based on personal sentiments. We saw that participants were worried about their privacy in combination with the app (27.4%) and their basic rights (20.1%). 14.9% stated both in combination.

Misconceptions and lack of information After asking participants how likely they will use the app (Q12), we asked for the primary reason for their installation intention (Q13) in free text form. As we saw many false beliefs, we coded the answers according to underlying misconceptions. We saw statements that were incorrect concerning the app's functionality and its data usage.

Some statements we observed were incorrect but might be correct with the further context of the answer. Participants who (probably) wanted to use the app, for example, stated: *"My safety"*, *"To protect myself"* or *"I want to stay healthy"*. Since the app cannot protect its users directly (users have already been exposed to infected people before they are warned) but only indirectly (the more people download the app, the more people might be influenced and will also download it, leading to better protection of all of its users), these answers indicate a misunderstanding of what the app can do for indi-

Gender	**Female**	55.9	**Male**	43.3	**Other**	0.8		
Age	**18-24**	24.2 (9.2)	**25-34**	14.3 (15.3)	**35-49**	23.9 (23.9)	**50-64**	26.8 (26.4)
	65+	10.9 (25.1)						
Education	**ISCED 0-2**	5.9 (16.5)	**ISCED 3-4**	48.9 (58.1)	**ISCED 5-8**	40.5 (25.4)	**Not disclosed**	2.2
Household Income	**<= 1300€**	18.3 (16)	**1300-1700€**	13.4 (8)	**1700-2600€**	20.8 (20)	**2600-3600€**	16.7 (18)
	3600-5000€	14.0 (17)	**>5000€**	6.2 (20)	**Not disclosed**	10.6		
Work Status	**School student**	4.7	**Univ./col. student**	9.8	**Employee**	48.9	**Civil servant**	2.0
	Self-employed	4.6	**Freelancer**	2.2	**Unemployed**	7.5	**Retiree**	16.9
	Not disclosed	3.4						
IT-Knowledge	**Yes**	20.9	**No**	74.9	**Not disclosed**	4.2		
Smartphone OS	**Android**	71.5	**iOS**	26.1	**Other**	2.4		
POLITICAL AFFILIATION	**The Greens**	21.6	**CDU/CSU**	19.4	**SPD**	11.7	**FDP**	6.7
	AfD	6.1	**The Left**	10.1	**Others**	24.5		
FEDERAL STATE	**BW**	12.9 (13.1)	**BY**	12.1 (15.6)	**BE**	7.0 (4.3)	**BB**	2.4 (3.1)
	HB	1.5 (0.8)	**HH**	3.6 (2.2)	**HE**	6.9 (7.5)	**MV**	2.4 (2.0)
	NI	6.7 (9.6)	**NW**	22.9 (21.6)	**RP**	4.6 (4.9)	**SL**	1.5 (1.2)
	SN	5.0 (5.0)	**ST**	4.7 (2.8)	**SH**	3.5 (3.5)	**TH**	2.4 (2.7)

Table 1: Participants' demographics (N= 744), in percentages. Numbers in brackets = the targeted distribution [17, 29].

vidual users.

Other answers were incorrect beyond doubt. One participant, for example, thought they would be able to see the number of current infections: *"To follow the spread of the pandemic"* (Probably will use the app).[7]

As already seen in Figure 5, participants believed the app would inform its users if infected people are close. This argument was used both as a positive as well as a negative reason to use the app. One participant probably wanted to use the app and argued: *"So I can see who is infected nearby to keep a larger distance to them and protect myself and fellow people."*. Another one did not want to use the app and wrote: *"The determination of the location is too inaccurate. It might happen that other people see me as infected, even though it is somebody else. I have concerns that this might lead to public hostilities or bullying."*

Participants also misunderstood what data will be used and shared: *"I don't want the government to know where I am in each and every second - especially as three other companies are involved as well"*[8] (Definitely will not use it) and *"I don't want the government to have all my numbers and names"* (Definitely will not use it).

Additional to the location misconception, we observed a participant who believed it would be necessary at all times to have access to the internet: *"I don't know how it works but if I need internet you can already forget about it, as I don't have mobile data."*. Anecdotally the participant was not able to correctly answer that the app will use Bluetooth.

Participants indicated that they are confused by the amount of (different) information: *"I don't have any trust. With all the news, I don't know what to believe anymore!!!"* (Probably not use the app). One participant, who failed the comprehension question and was undecided about the app, said: *"Everybody says the opposite of the others. Many say you lose your privacy."*

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[7]This is, in fact, possible since version 1.11 which was released at the end of January 2021 [37].

[8]It is not fully clear who the participants refers to. Telekom and SAP developed the app. Two research institutes advised. The RKI is publisher [13]

Following these answers and the data reported previously in this section, we conclude that many participants did not wholly understand the apps' functionality and thus assume a misconception in who will be protected by the app, what data it collects, and with whom the data will be shared.
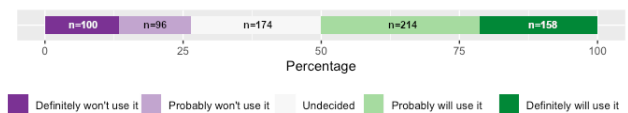

Figure 1: Reported intention to use the app.

4.3 Intention to use

Figure 1 shows the usage intention of all 744 participants. When looking at those participants who were very certain in what they will do, more participants indicated to definitely install the app (Def-Yes, 21.2 %) than to definitely not install it (Def-No, 13.4 %). Almost a third reported they will probably use the CWA (Prob-Yes, 28.8 %) compared to 12.9 % who reported to probably not use it (Prob-No). 23.4 % were still undecided (Undecided) about the installation. As of May 28, 2021 the reported download number of the CWA is 28 millions [22]. That estimates to around 46% of smartphone users in Germany [32]. This estimate does not take into account that that the same person could download the app onto multiple devices.

In the following, we report indications for reasons of the installation intention. For this, we selected an ordered logit regression with a model selection process via best AIC and BIC (c.f. Table 3). In the following paragraphs, we focus the report only on the statistically significant values.

Trust in Government Both trust and distrust of the government correlate heavily with app usage intention. The log odds for both "Somewhat distrust" and "Fully distrust" are proportionally negative compared to the neutral baseline (Log

Odds $= -0.56$ and -1.12 respectively). Contrarily, log odds for both "'Somewhat trust" and "Fully trust" are positive compared to the baseline (Log Odds $= 0.81$ and 1.88 respectively).

Worries Of the worries about future health, economy, and social life, only the health scale was included in the final model. All scale points of this scale are significant and show proportional positive log odds compared to the baseline of "No worries about health" (Log Odds in order of rising concern: 0.53, 0.76, and 1.21). This hints at a positive correlation between future health concerns and app usage intention.

Correlation with beliefs As previously reported, we identified many misconceptions. One of them ((SLF) GOVERNMENT SEES QUARANTINE VIOLATION) has a negative impact on the installation intention. Two other attributes that also negatively correlate with it are attributes that can neither be classified as correct or incorrect but are based on personal sentiment: (GEN) THREATS PRIVACY (Log Odds $= -1.33$) and (GEN) RESTRICTS BASIC RIGHTS (Log Odds $= -1.32$). (GEN) USES LOCATION SERVICES likely is an overestimation of the functionality and correlates positively with the intent to install. Another positive correlating attribute is (GEN) FIGHTS DISEASE SPREAD (Log Odds $= 0.55$). Its correctness is hard to measure, as there is no central entity that keeps records of how many people were warned by the app and thus ultimately prevented the spread of COVID-19.

Demographics & Personal Experiences We also were interested in which demographic factors and personal experiences with COVID-19 influence participants' decision to use the CWA. We found a statistically significant effect for "Not knowing" whether oneself or someone close was infected by COVID-19. There were negative log odds compared to the baseline of not being infected (Log Odds $= -0.84$). This could be due to a "Don't care" (instead of "Don't know") effect.

4.4 Potential Properties

As mentioned in Section 3, we presented the participants different hypothetical statements and consequences of the app (potential properties), asking whether and how that would influence their decision to use it (Q14). Table 7 in the Appendix shows whether these properties apply to the app as it was described pre-release or not and whether they describe a central or decentral property. We were particularly interested in seeing whether the centralized versus decentralized debate, in which computer scientists and privacy advocates were dominating, was reflected in the broader population's opinions. In the following, we highlight whether the properties belong to the centralized (C) or decentralized (D) approach or if they are independent of the apps' architecture and could be applied for both approaches (B).

Figure 2 shows all potential properties and the distribution of how they would influence the participants. It can be seen that no property is rated exclusively positively or negatively.

However, some have a clear negative tendency (i.e., (PP) HACKERS KNOW INFECTION STATUS, (PP) UNNECESSARY QUARANTINE DUE TO FALSE POSITIVE WARNING), or a clear positive tendency ((PP) WARNS ME IF EXPOSED TO COVID, (PP) HELPS RKI ASSESS SITUATION).

Usage intention All potential properties were rated from "Definitely would use it" to "Definitely would not use it". The answers of the participant differ visibly based on the previously stated general usage intention of the app as it was going to be released, i.e., participants who stated that they would want to install the app were more positive about all the potential properties than those who stated that they did not want to use the app and vice versa. We tested this observation with Kruskal-Wallis tests. The results show medium to large effects for all 23 potential properties [50]. This means that per property, there is at least one group that differs from the others in their rating. To find out more, we ran pairwise Wilcoxon rank-sum tests and corrected the p-values with a Bonferroni correction.[9] The poles ("Definitely will use the app" and "Definitely will not use the app") of the installation intention differ from all other groups for each property. Most but not all of the other group comparisons also show a statistically significant difference.

To assess the impact of each property, we report for each group whether the given answer suggests a positive, negative, or no change for the previously stated general intent to use the app. To clarify, if a participant stated that they wanted to install the to-be-released app, then any potential property which was rated "Definitely would use it", "Probably would be willing to use it" and "No influence on my willingness" would lead to no change in their intention and we summarize that as: "No change". However, for the same group, a property rated as either "Definitely would NOT use it" or "Probably would NOT be willing to use it" could lead to a negative effect on the previously positive attitude. We rated these properties as "negative change". The same goes for participants whose general usage intention was negative. Any negative properties would lead to "no change" while a positive property might lead to a "positive change". Participants who stated they were undecided could be swayed in either direction, so only properties rated with "No influence on my willingness" were rated with "no change", and the other received either a positive or negative rating.

We can see large differences between the usage intention groups (cf. Figure 6), especially when looking at the poles of the intention: participants who reported to definitely not use the app (Def-No) (Figure 6a) are seldom really positive

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[9]The effect sizes can be seen in the extended version of the paper: https://net.cs.uni-bonn.de/fileadmin/ag/smith/publications/2021_SOUPS_-_CWA.pdf.

WARNS ME IF EXPOSED TO COVID (B)* · | 16 | 51 | 37 | 105 | 241 | 294
HELPS RKI ASSESS SITUATION (C) | 21 | 48 | 30 | 151 | 237 | 257
RKI SEES MY CONTACTS TO INFORM OTHERS (C) | 19 | 67 | 63 | 124 | 215 | 256
INFORMS MY CONTACTS IF INFECTED (B) | 18 | 64 | 57 | 126 | 232 | 247
FASTER RETURN TO NORMAL (B)* | 24 | 51 | 30 | 157 | 243 | 239
RKI SEES INFECTED'S CONTACTS TO INFORM ME (B) | 16 | 58 | 54 | 122 | 258 | 236
TESTED BY IT EXPERTS (B)* | 26 | 53 | 44 | 155 | 249 | 217
TESTED BY BSI (B)* | 26 | 64 | 50 | 164 | 228 | 212
DATA PROTECTED BY GDPR (B)* | 20 | 55 | 56 | 181 | 230 | 202
INFORMS OTHERWISE UNINFORMED USERS (B)* | 28 | 53 | 41 | 159 | 264 | 199
TECHNICAL PROTECTION OF DATA (B)* | 22 | 62 | 39 | 165 | 258 | 198
LOCATION NOT COLLECTED (B)* | 20 | 57 | 47 | 178 | 244 | 198
DATA PROTECTED BY NEW LAW (B) | 32 | 64 | 55 | 184 | 233 | 176
FASTER ECONOMY RECOVERY (B)* | 32 | 58 | 39 | 228 | 230 | 157
HAS DATABASE OF INFECTED AND CONTACTS (C) | 28 | 97 | 99 | 171 | 195 | 154
WARNING RESULTS IN QUARANTINE ENFORCEMENT (B) | 27 | 98 | 108 | 189 | 182 | 140
USES MY LOCATION TO PROTECT OTHERS (-) | 23 | 113 | 117 | 164 | 194 | 133
ONLY LAW FORBIDS SURVEILLANCE (C) | 41 | 137 | 135 | 192 | 132 | 107
RKI SEES DISTANCE VIOLATION (C) | 25 | 167 | 146 | 210 | 113 | 83
CODE IS OPEN SOURCE (B)* | 148 | 93 | 70 | 260 | 96 | 77
UNNECESSARY TESTING DUE TO FALSE POSITIVE WARNING (B)* | 24 | 126 | 176 | 264 | 95 | 59
HACKERS KNOW INFECTION STATUS (D)* | 47 | 234 | 166 | 216 | 44 | 37

0   200   400   600
n

Legend: ■ Definitely yes □ No influence ■ Definitely not ■ Probably yes ■ Probably not ■ Don't know
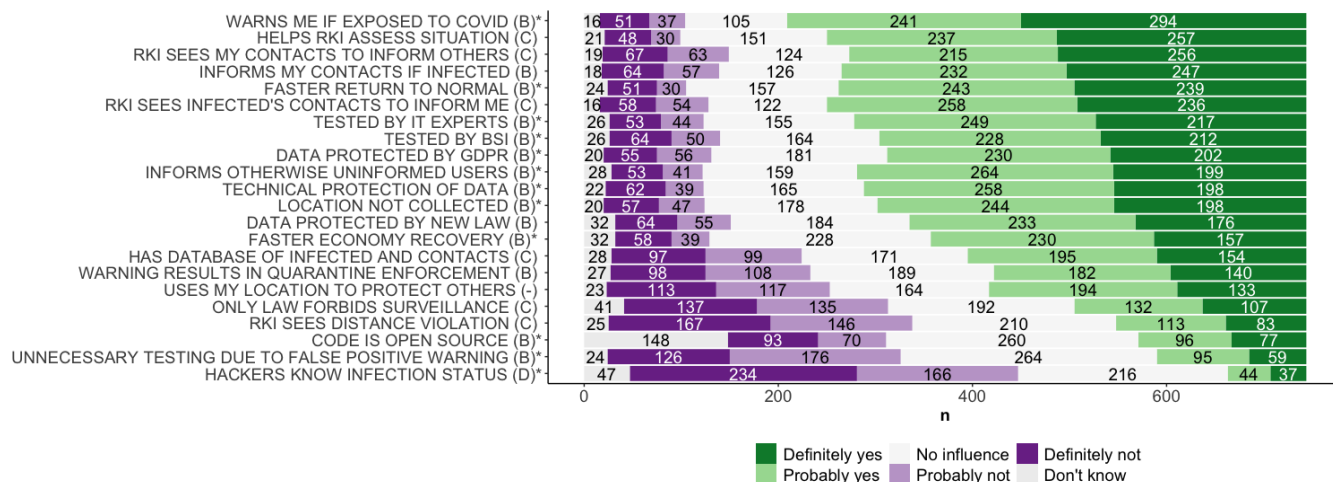
Figure 2: All presented potential properties and the distribution of the ratings of how these would influence the usage intention. * indicates that they apply to the real app. D = decentralized, C = centralized, B = both, "-" = not included in either app design

about any property. In contrast, participants who reported to definitely use the app (Def-Yes) (Figure 6e) are seldom very negative about any property.[10] While we can make no causal claims, the polarisation is noteworthy.

To better assess the individual effects of the different potential properties, we built an ordinal regression model based on a combined score of app usage intention and changes in intention due to these properties (cf. Table 4). Care needs to be taken when interpreting the regression model. Its intention is to highlight the direction of change as described above. However, since both the dependent and independent variables are non-equidistant and contain very strong poles (definitively use/definitively not use), the log odds should probably be seen as an upper bound of the change and needs to be used with care.

Twelve of the potential properties apply to the to-be-released app. Nine of those have a positive effect on usage intention, e.g., (PP) WARNS ME IF EXPOSED TO COVID (Log Odds = 1.52) and (PP) INFORMS OTHERWISE UNINFORMED USERS (Log Odds = 1.01). Both concern the fact that the app would notify users if they could have been at risk of contracting COVID-19. This was the main feature of the app as communicated to the population. Additionally, the intention to install the app increased if it would help returning to a pre-COVID-19 situation: (PP) FASTER RETURN TO NORMAL (Log Odds = 1.17) and (PP) FASTER ECONOMY RECOVERY (Log Odds = 0.81).

Two properties that apply to the app impacted the participants negatively: (PP) HACKERS KNOW INFECTION

STATUS (Log Odds = −1.48) and (PP) UNNECESSARY TESTING DUE TO FALSE POSITIVE WARNING (Log Odds = −0.87). The potential of being exposed by a hacker exists [47], but there are methods to mitigate this threat [20]. The risk for unnecessary testing applies to the app, but this could happen without the app and in both the central and decentral approaches.

Eleven potential properties do not apply to the app, of which five have a statistically significant positive influence on the app usage Three of them belong to the centralized approach and offer the Robert Koch-Institute (RKI) additional insights: (PP) HELPS RKI ASSESS SITUATION (Log Odds = 1.28), (PP) RKI SEES MY CONTACTS TO INFORM OTHERS (Log Odds = 1.12) and (PP) RKI SEES INFECTED'S CONTACTS TO INFORM ME (Log Odds = 1.20). (PP) INFORMS MY CONTACTS IF INFECTED (Log Odds = 1.15) includes the additional feature of warning users automatically if they had been in contact with an infected person. Currently, users have to actively share their positive test results if they want others to be warned [26].

Three potential properties that do not apply to the app had a negative influence on the installation intention. Two of them ((PP) RKI SEES DISTANCE VIOLATION (Log Odds = −0.87) and (PP) ONLY LAW PREVENTS SURVEILLANCE (Log Odds = −0.53)) open up the possibility of using the app for surveillance and can fall into the centralized approach; one ((PP) UNNECESSARY QUARANTINE DUE TO FALSE POSITIVE WARNING (Log Odds = −1.34)) could be seen as a clear disadvantage for the individual user.

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[10]High resolution versions of the figures can be found in the extended version, see Footnote. 9

Trust in different entities Some potential properties are connected to measures taken that should build trust regarding the CWA, regardless of the apps' design choices. These measures included different levels of (data) protection by law, experts testing the app, and the possibility to access the code itself.

As can be seen in Table 4, the idea to protect the data by a new law ((PP) DATA PROTECTED BY NEW LAW (Log Odds = 0.73)) as well as the existing protection by the GDPR ((PP) DATA PROTECTED BY GDPR (Log Odds = 0.88)) had a positive influence on the intention to use the CWA. Additionally, the technical protection of the data positively influenced the participants ((PP) TECHNICAL PROTECTION OF DATA (Log Odds = 1.00)). However, the participants did not seem to like the idea that the government would only be hindered by law to misuse the data for surveillance ((PP) ONLY LAW PREVENTS SURVEILLANCE (Log Odds = −0.53)).

It was also rated positively if the CWA would be tested by the German Federal Office for Information Security (BSI) ((PP) TESTED BY BSI (Log Odds = 0.9)) and experts ((PP) TESTED BY IT EXPERTS (Log Odds = 1.12)).

Interestingly unlike the expert discussion would have suggested, (PP) CODE IS OPEN SOURCE did not have a positive effect.

The influence of this property is not statistically significant and it received the most "I don't know" answers compared to all other properties. Even though the terminology "Open Source" is also used in Germany and was communicated in this way in the press release [38] in order to create transparency and trust, we believe many participants lacked an understanding of "Open Source". It thus does not yet seem to have the positive image the technical community would like it to have.

Perception of location services (PP) LOCATION NOT COLLECTED had a statistically significant positive influence on the installation intention (Log Odds = 1.10). (PP) USES MY LOCATION TO PROTECT OTHERS did not have a significant influence. At the beginning of the survey, we asked participants whether they believed the CWA would use location services. As a reminder: using the users' position was neither the case for the CWA nor was it communicated at any point. However, as mentioned in Section 4.2, the survey question asked about "location services", and Bluetooth may be known as such; therefore, participants could have interpreted it this way. We looked at whether the aspect of location services would make a difference for the installation intention. We compared the participants who a) thought that the CWA would use location services but not Bluetooth to b) those who did not believe the CWA uses location services regarding their general usage intention. 49.8 % of 197 vs 49.7 % of 298. We then also checked whether participants rated the potential properties more positive if they previously indicated that the CWA would use location services. Table 2 shows the percent-

ages of participants who were positively influenced by the property (i.e., answered "Probably would install it" or "Definitely would install it"), split by the general usage intention. As can be seen, the belief that the CWA uses location data did not positively affect the participants' sentiment when being asked how not enabling the government to see their current location would influence them.

5 Discussion

In the following section, we discuss our results, connect them with previous work, and propose directions for future research.

5.1 Participant Beliefs

The majority of the participants knew something about the CWA: Only 5.0% were not able to mark any of the correct app features as true, and the basic idea behind the CWA (that it would warn users with a risk of infection) was known by 59.5% (see Figure 4).

Bluetooth and Location Services We saw a lot of missing information. The technical details that the CWA would use Bluetooth were only known by 43.5%. Interestingly, 30.0% of the participants with some knowledge thought the CWA would use location services but not Bluetooth. . While this topic was discussed quite extensively in the media [10, 40], many people did not seem to think that the CWA would do tracing without GPS or the like. We also hypothesize that many who caught the term "Bluetooth" in the debate did not eliminate GPS from their mental model of the CWA. Another element that could get mixed up with information about the CWA might be the use of cellular network data to measure changes in mobility at the population level, as introduced earlier in the year [34]. Interestingly, we did not see any correlation between the assumption that the CWA uses location services and the usage intention.

Infected Persons Nearby 57.5 % of the participants believed the CWA would warn its users if an infected person is nearby. This was also found by Thomas et al. [66], who studied participants' knowledge regarding the already released Australian app and who found 57.4% of their participants believed this. It was also the most common misconception found by Williams et al. [72] (conducted in the UK). This belief seems very common, even if it was never planned nor (to our knowledge) communicated through official channels that the CWA would be able to warn users of infected persons in their vicinity directly. We are unaware of work that provides insight into why people assume this to be true. However, we hypothesize that many people mixed the two possible app features of being warned afterward and being alerted in real-time. With an incorrect understanding of how contacts are captured and in which cases the infection status is sent or downloaded,

the belief that the CWA could provide real-time warnings is not too far-fetched. Future research should investigate if such vital differences can be communicated, maybe even without going into technical details. It should be noted that this is an overestimation of the CWA's functionality and could lead to incautious behavior based on a false sense of security.

Privacy Concerns 27% of the participants believed the CWA would restrict their basic rights or threats their privacy. These beliefs had significant negative influences on usage intention. Related work found that one of the reasons participants did not want to use an app was because they feared data misuse or surveillance [59, 68]. Some even thought they would receive the names of infected persons [73]. Since the German app (CWA) follows the decentralized approach, only very little data is sent to a central server. While privacy concerns may be valid, we believe many participants did not follow the discussion enough to understand that data storage criticism only concerned the centralized approach. The decentralized app, which was being implemented, stored very little data centrally. We hypothesize they project the worries around the centralized app onto the decentralized one, even if not all concerns are plausible for this approach. Future research is needed to investigate how old mental models can be updated when the underlying system changes and what influences privacy perception. Although, usage intention does not seem to be driven by knowledge about technical details.

Usage Intention We looked at participants' knowledge and beliefs and how they are connected to participants' intentions to use the CWA. Only two attributes to which a correctness value can be assigned had a statistically significant impact on the participants' willingness to use the CWA. The misconception (OTH) GOVERNMENT SEES QUARANTINE VIOLATION had a negative impact, the correct attribute (SLF) INFORMS MY CONTACTS a positive one. The belief that one's privacy or basic rights were in danger lowered the willingness significantly. It increased if participants thought the CWA would help fight the spread. These assumptions do not reflect knowledge about the app but are based on personal estimations.

As discussed in Section 4.2, (GEN) USES LOCATION SERVICES is technically correct in some cases. If participants marked this attribute to be true for the CWA, they were significantly more willing to install the app. Even though the absence of location services as a potential property had a positive influence on using the CWA, participants did not value this absence with a higher usage intention even when previously thinking this would be the case. For this, we have two possible plausible explanations: a) people do not care about location service usage or b) other factors override concerns, e.g., believing in the necessity of the CWA.

Both hypotheses are valuable input for the HCI-community and should be further investigated.

Depending on this, it should be evaluated whether conjoint studies are reliable methods to measure possible acceptance in this domain and how the complexity of reality can be included (i.e., incomplete information or consequential thinking). It seems essential to know the participants' attitudes to the real objective of interest (in our case, the tracing app).

Whether to install the CWA or not seems primarily based on the sentiment of trust and the expectancy of a positive effect. This shows that it is important not only to develop trustworthy technologies but also to communicate their trustworthiness and effectiveness successfully. Technical measures aimed at creating trust do not automatically result in such (e.g., as seen for the CWA's open source property).

5.2 Demographic Factors

A study by Utz et al. [68] was conducted at the same time as this study in Germany and can thus be used to compare the results directly. While the authors conducted an experiment about hypothetical apps and how a tracing app could or should be built, we asked about an app that had been officially announced with a detailed description of features and was near launch. We can confirm part of their findings: We found a positive influence on the willingness to use a corona app a) if the opinion on state government was favorable, b) if participants were concerned about their health, and c) return to a normal life are possible due to the app. Participants with privacy concerns were less likely to use the app, which we can also confirm.

5.3 Never ever or no matter what

Like in our study, other researchers identified participants who did not like any app, regardless of its design choices [58, 62, 68]. We can confirm this finding. Participants within the Def-No group were mostly negative about any of the presented potential properties. 7.1% did not rate a single presented potential property as a positive change. This is similar to the reported 15-21% by Utz et al. [68]. We also saw the exact opposite: Participants belonging to the Def-Yes group rated every single theoretical additional aspect more positively than all other groups. For all potential properties, participants from the installation intention poles (Def-Yes and Def-No) give statistically significantly different answers compared to all other groups.

5.4 Centralized versus Decentralized

Large parts of the discussion around corona tracing apps concerned the technical approach and whether encounters between app users should be stored on a central server or the user's phone. Both approaches come with their advantages and disadvantages. For instance, the centralized app could

give the RKI[11] better insights into how people get infected. Since the central database would be in charge of selecting which users need to be warned, the RKI could see how many people are warned per positive case. Since the risk is computed on the users' devices in the decentralized app, the RKI does not know how many people receive warnings. In the centralized app, it would also have been possible to track how many other positive cases come out of any case, potentially giving more insights into how the virus spreads. On the other hand, the decentralized approach does not facilitate getting an overview but is also not in danger of being extended and misused for surveillance. In general, the centralized app, as it had been planned, offered more insights to healthcare professionals but bore a higher risk of compromise and misuse. However, it is worth noting that the decentralized approach relies on making anonymized infection information public on a central server. This opens the system up for local deanonymization attacks. Suppose an attacker can capture the ephemeral BT-IDs from a target and thus tying those IDs to that target. In that case, they can then monitor the system and see whether they report themselves as positive or not. The German app was based on the decentralized approach (see Section 2) due to public pressure to chose a more privacy-preserving approach. So in the context of this study, we were especially interested in how participants rate the possible benefits and dangers of a centralized app and to see if the debate led by researchers and privacy advocates well represented the feeling of the general public. We included 6 potential properties (Q14) in the survey that were connected to the centralized approach (Table 7). central: All in all, we saw a mix of sentiments. Three central potential properties (`(PP) RKI SEES INFECTED'S CONTACTS TO INFORM ME`, `(PP) RKI SEES MY CONTACTS TO INFORM OTHERS`, `(PP) HELPS RKI ASSESS SITUATION`) had a statistically significant positive influence on the intention to install. All three concern individual or societal benefits. Two other central properties (`(PP) RKI SEES DISTANCE VIOLATION`, `(PP) ONLY LAW PREVENTS SURVEILLANCE`) impacted the intention to install negatively. Both focus on the disadvantages of the centralized approach and do not have any clear advantage for the individual user.

The decentral property `(PP) HACKERS KNOW INFECTION STATUS` impacted the participants in a negative way. While this risk is limited to local attackers, and there are methods to mitigate this threat [20], it is something that our participants did not like. However, it did not feature significantly in the public debate as far as we know and, as such, is unlikely to have had much of an impact.

It seems participants are in general inclined to rate properties of the centralized approach positively while they rate the consequences (in the current technical landscape) that come with it rather low.

In summary, many of our participants had very positive views concerning the increased capabilities the centralized app would have had. This suggests that there could have been more support in the population for a more feature-rich app than academics and privacy advocates acknowledged in the discussion preceding the CWA's publication. Relevant health officials have since stated that the app in its current form is no great support [16], and due to the privacy design, it is hard to evaluate its efficacy. We think it is worth discussing whether a more nuanced discussion about the feature/privacy trade-off would be warranted for the future.

6   Conclusion

We surveyed the usage intention of the CWA in Germany right before its launch. 50% of the participants reported their intent to use the CWA, 26.3% refrained from usage and 23.4% were undecided. This seems reasonably close to the most recent (May 28, 2021) download numbers. To understand their decision, we investigated what beliefs participants had about the CWA. We saw many false beliefs, especially concerning technical details, i.e., 30.0% of the participants thought the CWA would use location services (other than Bluetooth). Actual knowledge about the CWA does not seem to be the primary driver for the decision to use the CWA. Instead, perceived privacy or basic rights intrusions led to a lower intention to use it. As also reported by other researchers, we found a positive effect when people were worried about general health and trusted the government. We also highlight that the general population's views were more diverse and more open to a central entity getting an overview to help fight the pandemic than the public discussion indicated. Based on our results, we recommend future work on a) where the privacy concerns come from, as in our view many of the concern did not match the actual CWA and b) how the perceptions can be aligned with the actual facts of the CWA, as this is necessary to discuss features based on the facts. And c) whether the CWA can be extended in a way that it becomes more useful to the relevant parties, e.g., the public health departments, while at the same time implementing technical countermeasures to prevent the data from being abused.

Acknowledgements

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[11]According to their website, "The Robert Koch Institute (RKI) is the government's central scientific institution [a federal government agency] in the field of biomedicine. It is one of the most important bodies for the safeguarding of public health in Germany." [31]

References

[1] AIC vs. BIC. https://www.methodology.psu.edu/resources/AIC-vs-BIC/. Accessed: June 09, 2021.

[2] Anteil der Nutzer von Social Networks in Europa nach ausgewählten Ländern 2020. https://de.statista.com/statistik/daten/studie/214663/umfrage/nutzung-von-social-networks-in-europa-nach-laendern/. Accessed: February 19, 2021.

[3] Bluetooth low energy. https://developer.android.com/guide/topics/connectivity/bluetooth-le#permissions. Accessed: May 29, 2021.

[4] Bundesinnenminister: Corona-Warn-App erfüllt höchste Ansprüche an Sicherheit und Datenschutz. https://www.bmi.bund.de/SharedDocs/kurzmeldungen/DE/2020/06/vorstellung-corona-warn-app.html. Accessed: February 17, 2021.

[5] Bundesregierung - Mythen und Falschmeldungen - Corona-Warn-App. https://web.archive.org/web/20200616193256/https://www.bundesregierung.de/breg-de/themen/mythen-und-falschmeldungen/corona-app-falschmeldungen-1758136. Accessed: February 02, 2021.

[6] Clickworker. www.clickworker.de/. Accessed: February 04, 2021.

[7] Contact Tracing Joint Statement. https://www.esat.kuleuven.be/cosic/sites/contact-tracing-joint-statement/. Accessed: January 28, 2021.

[8] CoroBlog zur wissenschaftlichen Auswertung der Corona-Datenspende-App. https://www.rki.de/DE/Content/InfAZ/N/Neuartiges_Coronavirus/Corona-Datenspende.html. Accessed: January 26, 2021.

[9] Corona-Apps im Überblick – Digitale Informations- und Hilfsangebote. https://www.zusammengegencorona.de/informieren/corona-warn-app/corona-apps-im-ueberblick/. Accessed: May 26, 2021.

[10] Corona-Pandemie: Alles Wissenswerte rund um die Warn-App. https://www.tagesschau.de/inland/faq-corona-tracing-app-101.html. Accessed: February 19, 2021.

[11] Corona-Tracing-App: Offener Brief an Bundeskanzleramt und Gesundheitsminister. https://www.ccc.de/de/updates/2020/corona-tracing-app-offener-brief-an-bundeskanzleramt-und-gesundheitsminister. Accessed: February 23, 2021.

[12] Corona-Tracing: Bundesregierung denkt bei App um. https://www.tagesschau.de/inland/coronavirus-app-107.html. Accessed: January 28, 2021.

[13] Corona-Warn-App: Fragen und Antworten. https://www.bundesregierung.de/breg-de/themen/corona-warn-app/corona-warn-app-faq-1758392. Accessed: February 23, 2021.

[14] Corona-Warn-App: Fragen und Antworten. https://www.verbraucherzentrale.de/wissen/digitale-welt/apps-und-software/coronawarnapp-fragen-und-antworten-zur-deutschen-tracingapp-47466. Accessed: February 17, 2021.

[15] Corona-Warn-App: Github. https://github.com/corona-warn-app. Accessed: February 17, 2021.

[16] Corona-Warn-App: Wenige Infektionen gemeldet (released October 2, 2020). https://www.aerzteblatt.de/archiv/216016/Corona-Warn-App-Wenige-Infektionen-gemeldet. Accessed: February 22, 2021.

[17] Einnahmen und Ausgaben privater Haushalte. https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Einkommen-Konsum-Lebensbedingungen/Einkommen-Einnahmen-Ausgaben/_inhalt.html. Accessed: May 29, 2020.

[18] Faktencheck: Nein, die Corona-Warn-App nutzt keine persönlichen Kontaktdaten. https://correctiv.org/faktencheck/2020/06/25/nein-die-corona-warn-app-nutzt-keine-persoenlichen-kontaktdaten/. Accessed: February 17, 2021.

[19] Fünf Monate nach dem Start: Die Tücken der Corona-Warn-App. https://www.tagesschau.de/inland/faq-corona-warn-app-101.html. Accessed: February 17, 2021.

[20] Google Exposure Notification Key Server. https://google.github.io/exposure-notifications-server/server_functional_requirements.html. Accessed: May 28, 2021.

[21] Help speed up contact tracing with TraceTogether. https://www.gov.sg/article/help-speed-up-contact-tracing-with-tracetogether. Accessed: February 09, 2021.

[22] Kennzahlen zur Corona-Warn-App. https://www.rki.de/DE/Content/InfAZ/N/Neuartiges_Coronavirus/WarnApp/Archiv_Kennzahlen/Kennzahlen_28052021.pdf?__blob=publicationFile. Accessed: June 1, 2021.

[23] Offener Brief: Geplante Corona-App ist höchst problematisch. http://www.fiff.de/presse/coronaappproblematisch. Accessed: January 28, 2021.

[24] Pan-European Privacy-Preserving Proximity Tracing. https://github.com/pepp-pt/pepp-pt-documentation/blob/master/10-data-protection/PEPP-PT-data-protection-information-security-architecture-Germany.pdf. Accessed: January 22, 2021.

[25] Pläne von Minister Spahn - Kritik an Corona-App wächst. https://www.tagesschau.de/inland/corona-app-spahn-101.html. Accessed: January 28, 2021.

[26] Poster: Positiv getestet? So teilen Sie Ihr Ergebnis über die Corona-Warn-App. https://www.rki.de/DE/Content/InfAZ/N/Neuartiges_Coronavirus/WarnApp/Poster.pdf?__blob=publicationFile. Accessed: June 09, 2021.

[27] Pressemitteilung des Bundesministeriums für Gesundheit, des Bundesministeriums des Innern, für Bau und Heimat und des Bundeskanzleramts zum Projekt "Corona-App" der Bundesregierung. https://www.bundesregierung.de/breg-de/aktuelles/pressemitteilung-des-bundesministeriums-fuer-gesundheit-des-bundesministeriums-des-innern-fuer-bau-und-heimat-und-des-bundeskanzleramts-zum-projekt-corona-app-der-bundesregierung-1747916. Accessed: January 28, 2021.

[28] Privacy notice CWA. https://www.coronawarn.app/assets/documents/cwa-privacy-notice-en.pdf. Accessed: February 23, 2021.

[29] Qualtrics. qualtrics.com. Accessed: January 22, 2021.

[30] Risikogruppen sind überall. https://de.statista.com/infografik/21145/groesse-von-ausgewaehlten-risikogruppen-in-deutschland/. Accessed: February 23, 2021.

[31] RKI - The Institute. https://www.rki.de/EN/Content/Institute/institute_node.html. Accessed: February 15, 2021.

[32] Statistiken zur Smartphone-Nutzung in Deutschland. https://de.statista.com/themen/6137/smartphone-nutzung-in-deutschland/. Accessed: February 23, 2021.

[33] Sylvia Limmer: Corona-Appidemie stoppen! https://www.afd.de/sylvia-limmer-corona-appidemie-stoppen/. Accessed: May 28, 2021.

[34] Süddeutsche Zeitung GmbH. https://sz.de/1.4850094. Accessed: February 25, 2021.

[35] Timeline of ECDC's reponse to COVID-19. https://www.ecdc.europa.eu/en/covid-19/timeline-ecdc-response. Accessed: February 09, 2021.

[36] Transkript: Erklärfilm zur „Corona-Warn-App". https://www.bundesregierung.de/resource/blob/1726066/1760258/c4247487c176123b13003e6125ead7aa/2020-06-10-corona-warn-app-de-textversion-data.pdf. Accessed: February 17, 2021.

[37] Version 1.11: Corona-Warn-App nun mit Kennzahlen zum Infektionsgeschehen. https://www.coronawarn.app/de/blog/2021-01-28-corona-warn-app-version-1-11/. Accessed: February 15, 2021.

[38] Veröffentlichung der Corona-Warn-App. https://www.bundesregierung.de/breg-de/themen/coronavirus/veroeffentlichung-der-corona-warn-app-1760892. Accessed: February 01, 2021.

[39] "Vorbildlich gelaufen" -Chaos Computer Club lobt deutsche Corona-App. https://www.zdf.de/nachrichten/politik/corona-app-launch-100.html. Accessed: February 17, 2021.

[40] Wann kommt die App, die hilft? https://www.zeit.de/digital/datenschutz/2020-04/corona-app-tracking-handydaten-bluetooth-datenschutz. Accessed: February 19, 2021.

[41] Washington Post-University of Maryland national poll, April 21-26, 2020. https://web.archive.org/web/20200501144955if_/https://www.washingtonpost.com/context/washington-post-university-of-maryland-national-poll-april-21-26-2020/3583b4e9-66be-4ed6-a457-f6630a550ddf/. Accessed: February 10, 2021.

[42] Wenn am nächsten Sonntag Bundestagswahl wäre ... https://www.wahlrecht.de/umfragen/forsa.htm. Accessed: January 27, 2021.

[43] Zwischenbilanz der Corona-Nachverfolgung: Wie erfolgreich funktionieren Corona-Apps in der EU? https://www.treffpunkteuropa.de/zwischenbilanz-der-corona-nachverfolgung-wie-erfolgreich-funktionieren. Accessed: February 23, 2021.

[44] "Decentralised Privacy-Preserving Proximity Tracing. https://github.com/DP-3T/documents/blob/master/DP3T%20White%20Paper.pdf. Accessed: January 22, 2021.

[45] Samuel Altmann, Luke Milsom, Hannah Zillessen, Raffaele Blasone, Frederic Gerdon, Ruben Bach, Frauke Kreuter, Daniele Nosenzo, Séverine Toussaert, and Johannes Abeler. Acceptability of app-based contact tracing for COVID-19: Cross-country survey study. *JMIR mHealth and uHealth*, 8(8):e19857, 2020.

[46] Patrik Bachtiger, Alexander Adamson, Jennifer K. Quint, and Nicholas S. Peters. Belief of having had unconfirmed Covid-19 infection reduces willingness to participate in app-based contact tracing. *NPJ digital medicine*, 3(1):1–7, 2020.

[47] Lars Baumgärtner, Alexandra Dmitrienko, Bernd Freisleben, Alexander Gruler, Jonas Höchst, Joshua Kühlberg, Mira Mezini, Markus Miettinen, Anel Muhamedagic, Thien Duc Nguyen, et al. Mind the gap: Security & privacy risks of contact tracing apps. *arXiv preprint arXiv:2006.05914*, 2020.

[48] Fabian Buder, Anja Dieckmann, Vladimir Manewitsch, Holger Dietrich, Caroline Wiertz, Aneesh Banerjee, Oguz A. Acar, and Adi Ghosh. Adoption Rates for Contact Tracing App Configurations in Germany, 2020.

[49] Kenneth P. Burnham and David R. Anderson. Multimodel inference: understanding AIC and BIC in model selection. *Sociological methods & research*, 33(2):261–304, 2004.

[50] Jacob Cohen. *Statistical power analysis for the behavioral sciences.* Academic press, 2013.

[51] Jemima A. Frimpong and Stephane Helleringer. Financial Incentives for Downloading COVID–19 Digital Contact Tracing Apps. SocArXiv 9vp7x, Center for Open Science, June 2020.

[52] M. Guillon and P. Kergall. Attitudes and opinions on quarantine and support for a contact-tracing application in France during the COVID-19 outbreak. *Public health*, 188:21–31, 2020.

[53] Eszter Hargittai, Elissa M. Redmiles, Jessica Vitak, and Michael Zimmer. Americans' willingness to adopt a COVID-19 tracking app. *First Monday*, 2020.

[54] Farkhondeh Hassandoust, Saeed Akhlaghpour, and Allen C. Johnston. Individuals' privacy concerns and adoption of contact tracing mobile applications in a pandemic: A situational privacy calculus perspective. *Journal of the American Medical Informatics Association*, 2020.

[55] Robert Hinch, Will Probert, Anel Nurtay, Michelle Kendall, Chris Wymant, Matthew Hall, Katrina Lythgoe, Ana Bulas Cruz, Lele Zhao, Andrea Stewart, et al. Effective configurations of a digital contact tracing app: A report to nhsx. *Retrieved July*, 23:2020, 2020.

[56] Kai T. Horstmann, Susanne Buecker, Julia Krasko, Sarah Kritzler, and Sophia Terwiel. Who does or does not use the "Corona-Warn-App" and why? *European Journal of Public Health*, 2020.

[57] Laszlo Horvath, Susan Banducci, and Oliver James. Citizens' Attitudes to Contact Tracing Apps. *Journal of Experimental Political Science*, pages 1–13, 2020.

[58] Gabriel Kaptchuk, Eszter Hargittai, and Elissa M. Redmiles. How good is good enough for COVID19 apps? The influence of benefits, accuracy, and privacy on willingness to adopt. *arXiv preprint arXiv:2005.04343*, 2020.

[59] Genia Kostka and Sabrina Habich-Sobiegalla. In Times of Crisis: Public Perceptions Towards COVID-19 Contact Tracing Apps in China, Germany and the US. *Germany and the US (September 16, 2020)*, 2020.

[60] Wassili Lasarov. Im Spannungsfeld zwischen Sicherheit und Freiheit. *HMD Praxis der Wirtschaftsinformatik*, pages 1–18, 2020.

[61] Tianshi Li, Camille Cobb, Sagar Baviskar, Yuvraj Agarwal, Beibei Li, Lujo Bauer, Jason I. Hong, et al. What Makes People Install a COVID-19 Contact-Tracing App? Understanding the Influence of App Design and Individual Difference on Contact-Tracing App Adoption Intention. *arXiv preprint arXiv:2012.12415*, 2020.

[62] Tianshi Li, Cori Faklaris, Jennifer King, Yuvraj Agarwal, Laura Dabbish, Jason I. Hong, et al. Decentralized is not risk-free: Understanding public perceptions of privacy-utility trade-offs in COVID-19 contact-tracing apps. *arXiv preprint arXiv:2005.11957*, 2020.

[63] Michael E. O'Callaghan, Jim Buckley, Brian Fitzgerald, Kevin Johnson, John Laffey, Bairbre McNicholas, Bashar Nuseibeh, Derek O'Keeffe, Ian O'Keeffe, Abdul Razzaq, et al. A national survey of attitudes to COVID-19 digital contact tracing in the Republic of Ireland. *Irish Journal of Medical Science*, pages 1–25, 2020.

[64] Elissa M. Redmiles. User Concerns & Tradeoffs in Technology-facilitated COVID-19 Response. *Digital Government: Research and Practice*, 2(1):1–12, 2020.

[65] Lucy Simko, Jack L. Chang, Maggie Jiang, Ryan Calo, Franziska Roesner, and Tadayoshi Kohno. COVID-19 Contact Tracing and Privacy: A Longitudinal Study of Public Opinion. *arXiv preprint arXiv:2012.01553*, 2020.

[66] Rae Thomas, Zoe A. Michaleff, Hannah Greenwood, Eman Abukmail, and Paul Glasziou. Concerns and Misconceptions About the Australian Government's COVIDSafe App: Cross-Sectional Survey Study. *JMIR public health and surveillance*, 6(4):e23081, 2020.

[67] Simon Trang, Manuel Trenz, Welf H. Weiger, Monideepa Tarafdar, and Christy MK Cheung. One app to trace them all? Examining app specifications for mass acceptance of contact-tracing apps. *European Journal of Information Systems*, 29(4):415–428, 2020.

[68] Christine Utz, Steffen Becker, Theodor Schnitzler, Florian M. Farke, Franziska Herbert, Leonie Schaewitz, Martin Degeling, and Markus Dürmuth. Apps against the spread: Privacy implications and user acceptance of covid-19-related smartphone apps on three continents.

In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*, CHI '21, New York, NY, USA, 2021. Association for Computing Machinery.

[69] Viktor von Wyl, Marc Hoeglinger, Chloe Sieber, Marco Kaufmann, Andre Moser, Miquel Serra-Burriel, Tala Ballouz, Dominik Menges, Anja Frei, and Milo A. Puhan. Drivers of acceptance of COVID-19 proximity tracing apps in Switzerland. *medRxiv*, 2020.

[70] Michel Walrave, Cato Waeterloos, and Koen Ponnet. Ready or Not for Contact Tracing? Investigating the Adoption Intention of COVID-19 Contact-Tracing Technology Using an Extended Unified Theory of Acceptance and Use of Technology Model. *Cyberpsychology, Behavior, and Social Networking*, 2020.

[71] Caroline Wiertz, Aneesh Banerjee, Oguz A. Acar, and Adi Ghosh. Predicted Adoption Rates of Contact Tracing App Configurations-Insights from a choice-based conjoint study with a representative sample of the UK population. *Available at SSRN 3589199*, 2020.

[72] Simon N. Williams, Christopher J. Armitage, Tova Tampe, and Kimberly Dienes. Public attitudes towards COVID-19 contact tracing apps: A UK-based focus group study. *Health Expectations*, 2020.

[73] Baobao Zhang, Sarah Kreps, Nina McMurry, and R. Miles McCain. Americans' perceptions of privacy and surveillance in the COVID-19 pandemic. *Plos one*, 15(12):e0242652, 2020.

A   Survey

Screening Questions

- Q1 What is your age?
  [Free Text]
- Q2 In which federal state do you live?
- Q3 Do you use a smartphone?
  [Yes, an Android / Yes, an IPhone / Yes, another smartphone / Yes, but I don't know which / No / I don't want to state]
- Q4 What is your netto household income?
  [<= 1300 / 1300-1700€ / 1700-2600€ / 2600-3600€ / 3600-5000€ / > 5000 / I don't want to state]
- Q5 What is the number of individuals living in your household?
  [1 / 2 / 3 / 4 or more / I don't want to state]
- Q6 What is the highest-level vocational qualification you hold?
  [Completed apprenticeship / Other; Vocational qualification: / University degree / Master or Technician certification or equivalent technical school diploma / Vocational school diploma / Technical school diploma / No vocational qualification / Technical college degree (or engineering school diploma) / I don't want to state / Abitur (German university entrance qualification)]

App Description and Media Sources

The COVID-19 coronavirus pandemic is a worldwide problem. The Corona warning app for Germany is one of the measures planned to assist health authorities in tracing and containing infection, being developed by SAP to run on Deutsche Telekom infrastructure. The Robert Koch Institute (RKI) will publish the app when it is ready. It is also referred to as the 'Corona app', 'COVID app' or 'contact tracing app'.

- Q7 Have you heard of the plans for this app? If 'yes', please select where you heard about the app. Multiple selections possible.
  [Public broadcasters (ARD, ZDF, WDR, etc.) / Non-public TV (Pro7, Vox, N24, etc.) / Scientific publications / Newspapers, journals, magazines, etc. / Family member / Official government/state agency websites (Robert Koch Institute, Federal Government, etc.) / Other websites: / I have not heard about this app / Friends / Social media (Twitter, Facebook, YouTube, TikTok, etc.) / Work colleagues/associates / Don't know/I don't want to state / Official Corona Warning App website]

Knowledge

- Q8 Which of the below statements do you think will apply regarding the app? (please check all that apply.)

  – The app uses Bluetooth.

  – Through the app I can donate health data to the Robert Koch Institute for research purposes.

  – The app determines when other smartphones are nearby that are also using the app.

  – The app shares temporary IDs and timestamps.

  – The app enables the government to see my current location.

  – The app enables the government to see if people are not keeping a safe distance from others.

  – Usage of the app will be mandatory.

  – The app shares the names and phone numbers of my contacts with the government.

  – The app infringes my basic rights.

  – The app can be used to demonstrate to others that I am not currently COVID-19 positive.

  – The app facilitates decision-making on who should be tested for COVID-19.

  – The app shares fitness data.

  – The app can help fight the spread of the COVID-19 virus.

  – The app uses location services (like GPS).

  – The app shares a profile of my movement.

  – None of the above applies.

  – Don't know

  – The app undermines my privacy.

- Q9 What statements do you think apply regarding the app when other users are COVID-19 positive? (please check all that apply.)

  – The app enables the government to see if someone is not complying with quarantine orders.

  – The app notifies me if I have had contact with an individual who later tested positive for COVID-19.

  – The app notifies me when an infected person is located nearby.

  – None of the above applies.

  – Don't know

- Q10 What statements do you think apply regarding the app when you yourself are COVID-19 positive? (please check all that apply.)

  – The app informs other app users who have been close to me that they may have contracted the virus.

  – The app sends data continuously to the RKI.

  – A physician or the public health authority has to confirm my positive COVID-19 test result before the app sends data to the RKI.

  – The app enables the government to see if I am not complying with quarantine orders.

  – None of the above applies.

  – Don't know

App Description and Comprehension

A brief introduction is provided below on the planned capabilities of the contact tracing app. The federal government intends to introduce a smartphone app to trace COVID-19 transmission in the near future. The app is to be very user-friendly and its usage voluntary. The app is designed to ensure that virus transmission is detected more quickly. This allows taking targeted containment measures.

When in use, the app determines what other users of the app are located near you. The app does this via Bluetooth. The app will alert you if you have been near someone within the past few days who subsequently tested positive for COVID-19. The app then informs you of what you need to do next, such as get tested for COVID-19.

- Q11 How will the described app determine what people have been near me?
  [Bluetooth / Location services (such as GPS) / My phone Contacts list / Don't know]

Install General

In answering the following questions, please imagine that the app described above has already been released. The app is being developed by SAP to run on Deutsche Telekom infrastructure. The Robert Koch Institute (RKI) is in charge of the app and evaluates the data. The exclusive permissible usage of the data is to fight COVID-19.

- Q12 How likely is it that you will use the app?
  [Definitely will use it / Probably will use it / Undecided / Probably will not use it / Definitely will not use it / Response declined / Don't know]

- Q13 What is the primary reason for your answer?
  [Free text]

Potential Properties

Q14 You will now be presented with 24 statements. These statements concern characteristics or things that **could** apply or be true with the app. Please select how these statements, **if true**, would influence your willingness to use the app.
[Definitely would use it / Probably would be willing to use it / No influence on my willingness / Probably would not be willing to use it / Definitely would not use it / Don't know]

- The government would be prevented by law, but not by technical means, from misusing the data for surveillance purposes.
- Using the app would enable the RKI to find out if I am not complying with minimum distancing to other individuals.
- The RKI would have a database with the contact data of infected individuals and the people they have had contact with.
- If I test positive for COVID-19, the app would allow the RKI to see who I had contact with in order to notify those individuals
- The German Federal Office for Information Security (BSI) would verify that the app fulfills data security and data protection requirements.
- Using the app would make possible a speedier return to normal public life.
- Technical measures would be implemented to ensure the data are protected.
- There is a possibility that the app could incorrectly report infection risk, resulting in me having to quarantine unnecessarily
- Using the app would help re-start the economy faster
- If the app notifies me that I may have been infected, I would have be required by law to quarantine.
- The app would notify me if I have been in a situation putting me at risk of contracting COVID-19.

- There is a possibility that the app could incorrectly report infection risk, resulting in me having to get tested unnecessarily
- Independent security experts would verify that the app fulfills data security and data protection requirements.
- The app would use information about my location to more accurately monitor infection risk for others
- Protection of the data would be guaranteed pursuant to a data protection policy and the General Data Protection Regulation.
- The app would not collect any data about my location.
- The app would inform people of infection risk who would not otherwise be contacted by the public health authority.
- Any nearby hackers could find out if I have tested positive for COVID-19.
- This question pertains to attentive completion of the survey. Please select "No influence" as response.
- If somebody near me has tested positive for COVID-19, the app would enable the RKI to see that I have had contact with that individual in order to notify me accordingly.
- Protection of the data would be guaranteed under a new law drafted especially for the app
- If I have tested positive for COVID-19, the app would automatically notify other users of the app who are at risk being exposed through contact with me
- The app would be open-source
- The app would support the RKI to better assess the COVID-19 situation.

It is being discussed whether use of the app should be made mandatory in certain situations where people come in contact in groups, such as patronizing restaurants or utilizing bus or train services, to facilitate targeted monitoring of infection risk. It must be considered however that roughly 20% of the German population would be excluded from using such services due to not having a smartphone.

- Q15 Would you approve or disapprove of such mandatory usage?
  [Approve entirely / Mainly approve / Neither approve nor disapprove / Mainly disapprove / Disapprove entirely / Response declined / Don't know]

Demographics

- Q16 What is your gender?
  [Male / Female / Non-binary / Would like to self-describe: / I don't want to state]

- Q17 What is your work status?
  [School student / University/college student / Employee / Civil servant / Self-employed / Freelancer / Unemployed / Retiree / I don't want to state]

- Q18 Do you have specialized computing skills, such as: system administration, programming, IT security, tech support, power user, etc?
  [Yes / No / I don't want to state]

- Q19 Please indicate your agreement or disagreement with the following: "I generally trust the government to do the right thing."
  [Fully agree / Mostly agree / Neither agree nor disagree / Mostly disagree / Fully disagree / I don't want to state]

- Q20 What party do you have the most affinity with?
  [The Greens / CDU/CSU / SPD / FDP / AfD / The Left / Others/I don't want to state]

- Q21 Currently, how frequently do you have close personal contact with people not from your household?
  [Once a week at most / A few times a week / A few times a day / Several times a day / I don't want to state]

- Q22 How concerned or unconcerned are you about COVID-19 in regard to the following three areas?
  Health, The economy, Society
  [Unconcerned / A bit concerned / Concerned / Very concerned / I don't want to state]

- Q23 Do you fall within a COVID-19 high-risk group?
  [Yes / No / Don't know / I don't want to state]

- Q24 Does someone close to you fall within a COVID-19 high-risk group?
  [Yes / No / Don't know / I don't want to state]

- Q25 Have you or any person close to you fallen ill with Covid-19?
  [Yes / No / Don't know / I don't want to state]

- Q26 Has anyone close to you died of Covid-19?
  [Yes / No / Don't know / I don't want to state]

- Q27 How has the Covid-19 pandemic affected you financially?
  [Positive impact / No impact / Negative impact / Critical impact / I don't want to state]

- Q28 Has the Covid-19 pandemic resulted in you having to look after/care for someone at home?
  [Yes / No / I don't want to state]

- Q29 How has the crisis affected your work?
  [Unaffected / Working from home / Short-time work / Became unemployed / Found employment / I don't want to state]
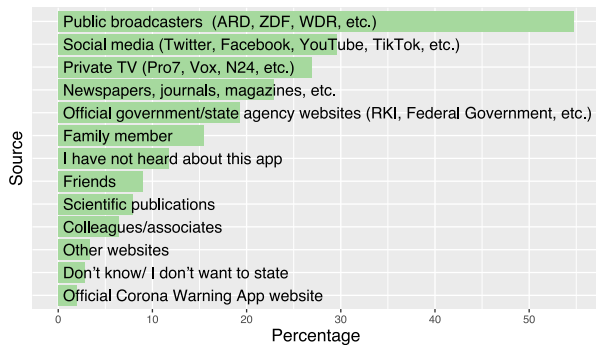
B   Additional Tables and Figures

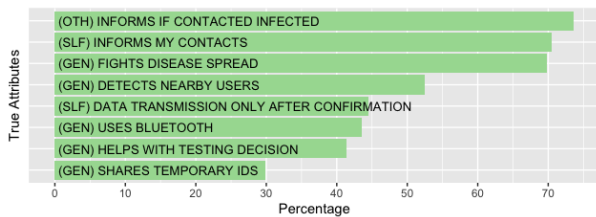Figure 3: Frequency of reported information sources (n=744).

Figure 4: Attributes that are correct for the current app and the percentage of participants who checked the corresponding box. OTH: other is infected, SLF: self infected, GEN: general attribute
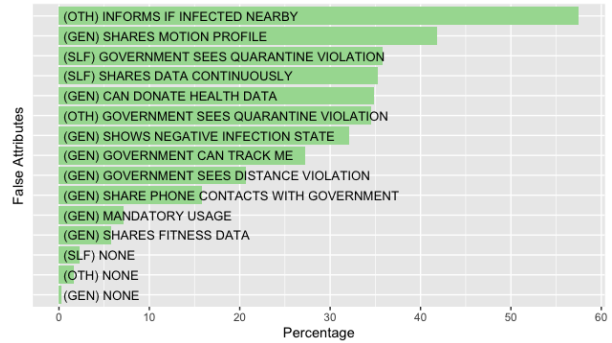

Figure 5: Attributes that are wrong for the current app and the percentage of participants that checked the corresponding box.

Usage intention	LBNB belief?	Positive influence if no location usage
Undecided	Yes (n= 46)	26.1%
	No (n= 108)	28.7%
Prob-No	Yes (n= 27)	3.7%
	No (n= 53)	15.1%
Def-No	Yes (n= 25)	4%
	No (n= 65)	7.7%

Table 2: Percentage of participants who rated the potential property that the app would not collect data about users' position positively based on their general usage intention and whether they believed the app would be working with location data. LBNB = Location service but no Bluetooth.

Factor	Log Odds	C.I.	p-value
Trust in Government (Q19)			
Trust: Fully agree	1.88	[1.26, 2.50]	< 0.001∗
Trust: Somewhat agree	0.81	[0.41, 1.20]	< 0.001∗
Trust: Somewhat disagree	−0.56	[−1.08, −0.04]	0.035∗
Trust: Fully disagree	−1.12	[−1.85, −0.39]	0.003∗
Beliefs			
(GEN) THREATS PRIVACY	−1,33	[−1.82, −0.84]	< 0.001∗
(GEN) FIGHTS DISEASE SPREAD	0.55	[0.16, 0.94]	0.005∗
(GEN) RESTRICTS BASIC RIGHTS	−1.32	[−1.88, −0.77]	< 0.001∗
(OTH) GOVERNMENT SEES QUARANTINE VIOLATION	−0.70	[−1.08, −0.33]	< 0.001∗
(SLF) INFORMS MY CONTACTS	0.51	[0.15, 0.88]	0.006∗
(GEN) MANDATORY USAGE	0.66	[−0.07, 1.39]	0.075
(GEN) USES LOCATION SERVICES	0.42	[0.06, 0.77]	0.022∗
(SLF) DATA TRANSMISSION ONLY AFTER CONFIRMATION	0.31	[−0.02, 0.65]	0.069
(OTH) INFORMS IF INFECTED NEARBY	−0.28	[−0.61, 0.06]	0.107
Worries (Q22)			
Health: Somewhat worried	0.53	[0.04, 1.02]	0.036∗
Health: Worried	0.76	[0.24, 1.28]	0.004∗
Health: Very worried	1.21	[0.63, 1.79]	< 0.001∗
Media Sources (Q7)			
Media: Off. Homepage	0.99	[−0.14, 2.12]	0.085
Media: Publications	0.62	[0.07, 1.18]	0.028∗
Media: Public Broadcasters	−0.30	[−0.63, 0.04]	0.082
Personal Experience (Q25)			
Was or knows infected: Yes	−0.06	[−0.63, 0.51]	0.840
Was or knows infected: Don't know	−0.84	[−1.57, −0.11]	0.024∗
Demographics (Q16, Q18)			
Tech Background	0.24	[−0.14, 0.62]	0.208
Intercepts (App usage intention)			
Definitely not | Probably not	−1.99	[−2.61, −1.37]	< 0.001∗
Probably not | Undecided	0.35	[0.14, 0.56]	0.001∗
Undecided | Probably would	0.53	[0.38, 0.68]	< 0.001∗
Probably would | Definitely would not	0.61	[0.48, 0.74]	< 0.001∗

Table 3: Results of the final ordered logit regression model correlating factors with app usage intention. "Don't want to answer" answers were omitted. See Section 3.5 and Table 5 for further details.

Factor	Log Odds	C.I.	p-value
(PP) WARNS ME IF EXPOSED TO COVID	1.52	[1.31, 1.73]	< 0.001∗
(PP) INFORMS MY CONTACTS IF INFECTED	1.15	[0.94, 1.37]	< 0.001∗
(PP) INFORMS OTHERWISE UNINFORMED USERS	1.01	[0.80, 1.23]	< 0.001∗
(PP) HELPS RKI ASSESS SITUATION	1.28	[1.07, 1.49]	< 0.001∗
(PP) FASTER RETURN TO NORMAL	1.17	[0.96, 1.39]	< 0.001∗
(PP) FASTER ECONOMY RECOVERY	0.81	[0.59, 1.03]	< 0.001∗
(PP) RKI SEES MY CONTACTS TO INFORM OTHERS	1.12	[0.90, 1.33]	< 0.001∗
(PP) RKI SEES INFECTED'S CONTACTS TO INFORM ME	1.20	[0.98, 1.41]	< 0.001∗
(PP) HACKERS KNOW INFECTION STATUS	−1.48	[−1.69, −1.27]	< 0.001∗
(PP) RKI SEES DISTANCE VIOLATION	−0.87	[−1.09, −0.65]	< 0.001∗
(PP) USES MY LOCATION TO PROTECT OTHERS	−0.10	[−0.33, 0.12]	0.359
(PP) UNNECESSARY QUARANTINE DUE TO FALSE POSITIVE WARNING	−1.34	[−1.55, −1.13]	< 0.001∗
(PP) UNNECESSARY TESTING DUE TO FALSE POSITIVE WARNING	−0.87	[−1.09, −0.66]	< 0.001∗
(PP) WARNING RESULTS IN QUARANTINE ENFORCEMENT	0.04	[−0.18, 0.27]	0.709
(PP) HAS DATABASE OF INFECTED AND CONTACTS	0.18	[−0.04, 0.41]	0.105
(PP) DATA PROTECTED BY NEW LAW	0.73	[0.52, 0.95]	< 0.001∗
(PP) DATA PROTECTED BY GDPR	0.88	[0.67, 1.10]	< 0.001∗
(PP) TECHNICAL PROTECTION OF DATA	1.00	[0.79, 1.22]	< 0.001∗
(PP) TESTED BY BSI	0.90	[0.69, 1.12]	< 0.001∗
(PP) TESTED BY IT EXPERTS	1.12	[0.91, 1.33]	< 0.001∗
(PP) LOCATION NOT COLLECTED	1.10	[0.88, 1.31]	< 0.001∗
(PP) CODE IS OPEN SOURCE	−0.12	[−0.34, 0.10]	0.277
(PP) ONLY LAW PREVENTS SURVEILLANCE	−0.53	[−0.75, −0.31]	< 0.001∗
Neg. change | No change	−1.89	[−2.05, −1.74]	< 0.001∗
No change | Pos. change	1.33	[1.31, 1.35]	< 0.001∗

Table 4: Ordered logit regression model correlating different app properties against a combined "Usage Intention Change" scale ranging from 'Negative change' to "Positive change".

Factor	Description	Baseline
Required		
Trust in Government	5-point scale. Fully trust to fully distrust towards the government.	Neither
Optional		
Beliefs	3 multi-choice questions. Beliefs about the app in general, personal context, and related to others.	n/a
Worries	3 questions; 4-point scales. How worried are participants regarding future health, economy, and social life.	Not worried
Media Sources	Multi-choice question. From which media sources participants learned about the app.	n/a
Personal	6 questions; Yes, No & "Don't know". Health risks, previous infection, deaths, and other personal effects.	No
Demographics	7 questions. General demographic questions such as tech background, age, gender, and job.	various

Table 5: Factor categories appearing in the candidate regression models. Model candidates always included the required factors and covered all possible combinations of optional factors. Final models were selected based on lowest AIC. Categorical factors are individually compared to their listed baseline.

| Abbreviation	Question	True?
General attributes		
(GEN) SHARES MOTION PROFILE	The app shares a profile of my movement.	✗ [36]
(GEN) SHARES TEMPORARY IDS	The app shares temporary IDs and timestamps.	✓ [38]
(GEN) SHARE PHONE CONTACTS WITH GOVERNMENT	The app shares the names and phone numbers of my contacts with the government.	✗ [18]
(GEN) GOVERNMENT CAN TRACK ME	The app enables the government to see my current location.	✗ [36]
(GEN) THREATS PRIVACY	The app undermines my privacy.	-
(GEN) DETECTS NEARBY USERS	The app determines when other smartphones are nearby that are also using the app.	✓ [38]
(GEN) HELPS WITH TESTING DECISION	The app facilitates decision-making on who should be tested for COVID-19.	✓ [19]
(GEN) SHARES FITNESS DATA	The app shares fitness data.	✗ [9]
(GEN) SHOWS NEGATIVE INFECTION STATE	The app can be used to demonstrate to others that I am not currently COVID-19 positive.	✗
(GEN) FIGHTS DISEASE SPREAD	The app can help fight the spread of the COVID-19 virus.	✓ [38]
(GEN) CAN DONATE HEALTH DATA	Through the app I can donate health data to the RKI for research purposes.	✗ [9]
(GEN) RESTRICTS BASIC RIGHTS	The app infringes my fundamental rights.	-
(GEN) GOVERNMENT SEES DISTANCE VIOLATION	The app enables the government to see if people are not keeping a safe distance from others.	✗ [14]
(GEN) USES LOCATION SERVICES	The app uses location services (like GPS).	- [3, 14]
(GEN) MANDATORY USAGE	Usage of the app will be mandatory.	✗ [38]
(GEN) USES BLUETOOTH	The app uses Bluetooth.	✓ [38]
(GEN) NONE	None of the above applies	✗
Attributes if others are infected		
(OTH) INFORMS IF INFECTED NEARBY	The app notifies me when an infected person is located nearby.	✗ [14]
(OTH) INFORMS IF CONTACTED INFECTED	The app notifies me if I have had contact with an individual who later tested positive for COVID-19.	✓ [38]
(OTH) GOVERNMENT SEES QUARANTINE VIOLATION	The app enables the government to see if someone is not complying with quarantine orders.	✗ [14]
(OTH) NONE	None of the above applies	✗
Attributes if I myself am infected		
(SLF) DATA TRANSMISSION ONLY AFTER CONFIRMATION	A physician or the public health authority has to confirm my positive COVID-19 test result before the app sends data to the RKI.	✓ [14]
(SLF) INFORMS MY CONTACTS	The app informs other app users who have been close to me that they may have contracted the virus.	✓ [38]
(SLF) GOVERNMENT SEES QUARANTINE VIOLATION	The app enables the government to see if I am not complying with quarantine orders.	✗ [14]
(SLF) SHARES DATA CONTINUOUSLY	The app sends data continuously to the RKI.	✗ [14]
(SLF) NONE	None of the above applies	✗

Table 6: Overview of all statements the participants were presented with and for which they had to decide whether they apply to the to be released CWA. The last column indicates if the attribute is correct for the app.

| Abbreviation (Potential Property)	Full statement	True?	Approach (Central/Decentral/Both)
(PP) ONLY LAW PREVENTS SURVEILLANCE	The government would be prevented by law, but not by technical means, from misusing the data for surveillance purposes.	✗ [28]	C
(PP) TECHNICAL PROTECTION OF DATA	Technical measures would be implemented to ensure the data are protected.	✓ [28]	B
(PP) RKI SEES INFECTED'S CONTACTS TO INFORM ME	If somebody near me has tested positive for COVID-19, the app would enable the RKI to see that I have had contact with that individual in order to notify me accordingly.	✗ [28]	C
(PP) RKI SEES MY CONTACTS TO INFORM OTHERS	If I test positive for COVID-19, the app would allow the RKI to see who I had contact with in order to notify those individuals.	✗ [28]	C
(PP) RKI SEES DISTANCE VIOLATION	Using the app would enable the RKI to find out if I am not complying with minimum distancing to other individuals.	✗ [28]	C
(PP) HAS DATABASE OF INFECTED AND CONTACTS	The RKI would have a database with the contact data of infected individuals and the people they have had contact with.	✗ [28]	C
(PP) HELPS RKI ASSESS SITUATION	The app would support the RKI to better assess the COVID-19 situation.	✗	C
(PP) USES MY LOCATION TO PROTECT OTHERS	The app would use information about my location to more accurately monitor infection risk for others.	✗ [14]	-
(PP) LOCATION NOT COLLECTED	The app would not collect any data about my location.	✓ [14]	B
(PP) TESTED BY BSI	The German Federal Office for Information Security(BSI) would verify that the app fulfills data security and data protection requirements.	✓ [4]	B
(PP) FASTER RETURN TO NORMAL	Using the app would make possible a speedier return to normal public life.	✓ [55]	B
(PP) UNNECESSARY QUARANTINE DUE TO FALSE POSITIVE WARNING	There is a possibility that the app could incorrectly report infection risk, resulting in me having to quarantine unnecessarily.	✗ [13]	B
(PP) FASTER ECONOMY RECOVERY	Using the app would help restart the economy faster.	✓	B
(PP) WARNING RESULTS IN QUARANTINE ENFORCEMENT	If the app notifies me that I may have been infected, I would have be required by law to quarantine.	✗ [13]	B
(PP) WARNS ME IF EXPOSED TO COVID	The app would notify me if I have been in a situation putting me at risk of contracting COVID-19.	✓ [38]	B
(PP) UNNECESSARY TESTING DUE TO FALSE POSITIVE WARNING	There is a possibility that the app could incorrectly report infection risk, resulting in me having to get tested unnecessarily.	✓ [19]	B
(PP) TESTED BY IT EXPERTS	Independent security experts would verify that the app fulfills data security and data protection requirements.	✓ [39]	B
(PP) DATA PROTECTED BY GDPR	Protection of the data would be guaranteed pursuant to a data protection policy and the General Data Protection Regulation.	✓ [28]	B
(PP) INFORMS OTHERWISE UNINFORMED USERS	The app would inform people of infection risk who would not otherwise be contacted by the public health authority.	✓ [38]	B
(PP) HACKERS KNOW INFECTION STATUS	Any nearby hackers could find out if I have tested positive for COVID-19.	✓ [47]	D
(PP) DATA PROTECTED BY NEW LAW	Protection of the data would be guaranteed under a new law drafted especially for the app.	✗	B
(PP) INFORMS MY CONTACTS IF INFECTED	If I have tested positive for COVID-19, the app would automatically notify other users of the app who are at risk being exposed through contact with me.	✗ [28]	B
(PP) CODE IS OPEN SOURCE	The app would be open-source	✓ [15]	B

Table 7: The presented potential properties are either true for the centralized (C) or the decentralized (D) approach, or true for both (B) app designs. The properties that did not depend on the design approach is marked with "-".

Currently, how frequently do you have close personal contact with people not from your household?					
Once a week at most	39.5	A few times a week	37.8	A few times a day	10.2	Several times a day	10.1
Not disclosed	2.4						

How concerned or unconcerned are you about COVID-19 in regard to the following three areas?					
Health							
Unconcerned	16.0	A bit concerned	39.4	Concerned	25.7	Very concerned	18.3
Not disclosed	0.7						
The economy							
Unconcerned	7.3	A bit concerned	22.5	Concerned	34.5	Very concerned	35.2
Not disclosed	0.5						
Society							
Unconcerned	11.3	A bit concerned	23.9	Concerned	35.8	Very concerned	28.1
Not disclosed	0.9						

Do you fall within a COVID-19 high-risk group?					
Yes	31.1	No	58.1	Don't know	9.8	Not disclosed	1.9

Does someone close to you fall within a COVID-19 high-risk group?					
Yes	62.2	No	31.3	Don't know	5.8	Not disclosed	0.7

Have you or any person close to you fallen ill with Covid-19?					
Yes	7.5	No	86.8	Don't know	5.0	Not disclosed	0.7

Has anyone close to you died of Covid-19?					
Yes	3.0	No	94.9	Don't know	1.8	Not disclosed	0.4

How has the Covid-19 pandemic affected you financially?					
Positive impact	3.2	No impact	58.9	Negative impact	32.4	Critical impact	3.2
Not disclosed	2.3						

Has the Covid-19 pandemic resulted in you having to look after/care for someone at home?				
Yes	9.4	No	89.9	Not disclosed	0.7

| **How has the crisis affected your work?**					
Unaffected	52.7	Working from home	24.5	Short-time work	13.6	Became unemployed	5.0
Found employment	0.9	Not disclosed	3.4				

Table 8: Impact of the Covid-19 pandemic on participants. Numbers report the percentages in each question ($n = 744$)
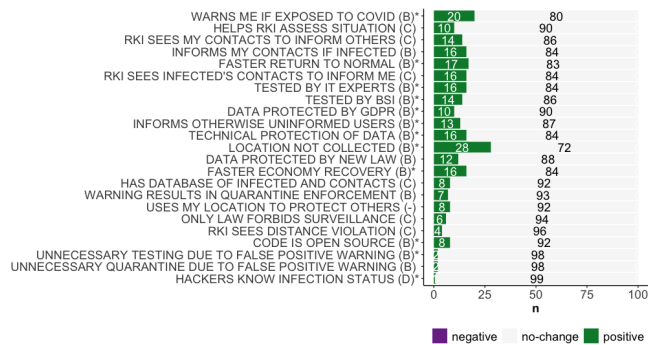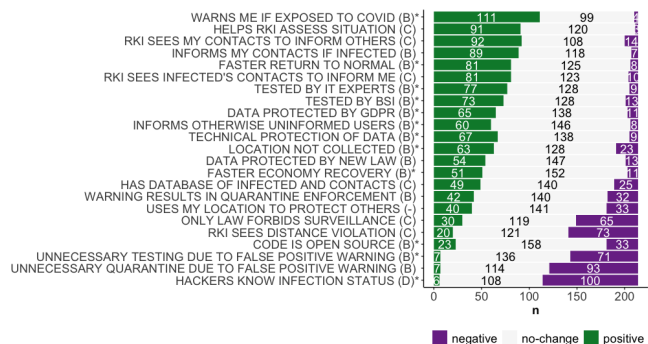
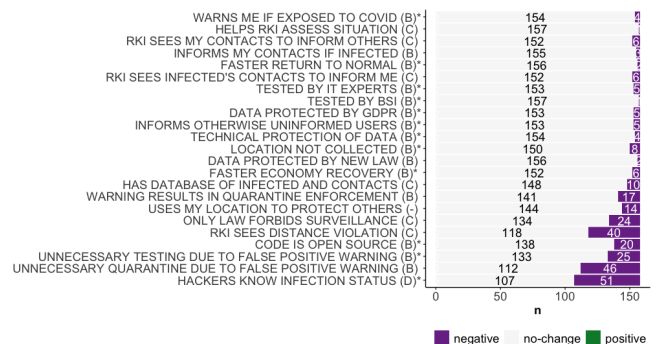(a) Potential properties and the distribution of *Def-No* participants. $n = 100$
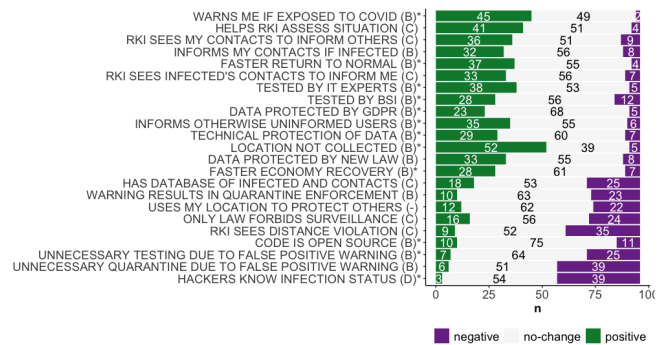
(b) Potential properties and the distribution of *Prob-No* participants. $n = 96$
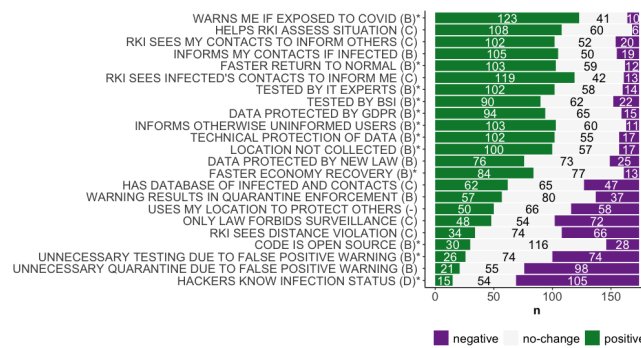
(c) Potential properties and the distribution of *Undecided* participants. $n = 174$

(d) Potential properties and the distribution of *Prob-Yes* participants. $n = 214$

(e) Potential properties and the distribution of *Def-Yes* participants. $n = 158$

Figure 6: Participants perception of potential properties, spilt by their general usage intention. * indicate properties that apply to the real app. D = Dezantal, C = Central, B = Both