# Not Only for Contact Tracing: Use of Belgium's Contact Tracing App among Young Adults

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Many countries developed and deployed contact tracing apps to reduce the spread of the COVID-19 coronavirus. Prior research explored people's intent to install these apps, which is necessary to ensure effectiveness. However, adopting contact tracing apps is not enough on its own, and much less is known about how people actually use these apps. Exploring app use can help us identify additional failures or risk points in the app life cycle. In this study, we conducted 13 semi-structured interviews with young adult users of Belgium's contact-tracing app, Coronalert. The interviews were conducted approximately a year after the onset of the COVID-19 pandemic. Our findings offer potential design directions for addressing issues identified in prior work – such as methods for maintaining long-term use and better integrating with the local health systems – and offer insight into existing design tensions such as the trade-off between maintaining users' privacy (by minimizing the personal data collected) and users' desire to have *more* information about an exposure incident. We distill from our results and the results of prior work a framework of people's decision points in contact-tracing app use that can serve to motivate careful design of future contact tracing technology.

CCS Concepts: • **Security and privacy** → **Usability in security and privacy**.

Additional Key Words and Phrases: COVID-19 , User Study , Privacy , Contact Tracing , Interviews , Decision Model

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## 1 INTRODUCTION

The onset of the COVID-19 pandemic inspired technologists to join the public health fight. While a number of different technological interventions were proposed to keep people safe, one of the most widespread interventions were contact-tracing or exposure-notification apps. These apps are designed to track people's contact with others and notify them if they have been exposed to COVID-19. A sizable body of prior work finds the apps are privacy-sensitive and controversial [e.g., [44, 62]].

While contact-tracing technologies had been prototyped and in some cases deployed prior to the COVID-19 pandemic (hereafter, the pandemic) [1, 13, 14, 47], they were never deployed at such large scale [44]. A flurry of academic research was launched at the first mention of the potential use of these apps during the pandemic,

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investigating what concerns people would have with installation [10, 24, 26, 37, 38, 40–42, 48, 54, 56, 62–64]. As the public health – and individual – benefits of these apps scale exponentially [11] with the number of users, considering barriers to adoption is indeed critical. However, adoption is not the only critical point in ensuring that contact-tracing apps offer public health benefits: it is also critical to understand how users use the apps, whether they are able to do so effectively, and whether they receive the expected individual benefits.

To answer these use-related questions, we investigate the use of Belgium's Coronalert app, a contact-tracing app built on the Google-Apple Exposure Notification framework that has been widely leveraged to build contact-tracing apps in the West [22]. Specifically, we conduct a qualitative interview study with Coronalert app users, including those who received exposure notifications and/or tested positive during their use of the app. The study participants were young adults (aged 21-36 years), 10 of whom were university students. We investigate our participants' (1) use of Coronalert, (2) perceptions of the app's efficacy, and (3) mental models, including how those mental models influence both use and perceptions. Ultimately, we synthesize a set of common contact tracing app use cases and connect our results with the results of prior research to propose a model of key decision-making points in contact-tracing app use. Such a model can be leveraged to improve the public health and individual benefits of similar technologies. Further, we highlight design opportunities for issues highlighted in prior work, such as ensuring sustained use throughout the pandemic [57] and methods for integrating with the local health system [4].

## 2 RELATED WORK

The success of digital contact tracing in controlling virus transmission heavily depends on the proportion of the overall population that participates in the process [20]. In "participating", people are required to *install* contact-tracing apps. A sizable body of prior work explored why people may choose to install or not install COVID-19 contact tracing apps and how to motivate them to do so [7, 10, 15, 25, 26, 32, 33, 37–42, 46, 48, 49, 54–56, 59, 62–64]. These studies found that people had multiple adoption considerations, including the app's functionality (i.e., what it will do, how effectively it will do it, and at what costs), and privacy and data-collection risks. However, it is not enough for people simply to install contact tracing apps: they must *use* them appropriately. In our study, we focus on this aspect of people's participation in the process of contact tracing: people's actual use of these apps.

Prior work focused on contact tracing app use varies in the objectives and methodologies used, and in the explored apps, which differ in their types and design stages. The main privacy design aspects of contract tracing apps refer to the data collected and the app's architecture, which defines the location of the stored data. An app can collect various combinations of location and proximity data. Proximity data is considered to be less sensitive than location, which raises users' concerns [60] and can be used to infer other personal information such as health condition [2]. As for the app's architecture, the data can be either stored and processed locally (decentralized) or in central servers (centralized), which put the users' personal information at higher risk.

A limited body of work has explored people's use of deployed contact-tracing apps. Many of these works focus on collecting user sentiment toward real-world apps prior to deployment, for example using real apps as design prompts for user experience focus groups, testing, and cognitive interviews [4, 27, 35, 36, 50, 52]. Findings showed that for some apps, while users were positive about the apps' usability [4, 36], they demonstrated misunderstandings regarding some of the apps' functions, such as check-in [27], exposure notification [4, 34], and sharing the test results [4]. To build on these results, there is a need to investigate users' mental models in contexts outside of pre-deployment lab settings [4].

Seven prior works have explored people's experiences with using contact tracing apps in the wild. Wang et al. [61] examine people's attitudes toward contact tracing apps when they were first released (before July 2020) by examining their reviews of eight contact tracing apps (four from Europe, three from Asia, and one from Australia).

They highlight multiple technical issues with these apps, including issues related to Bluetooth functionality and privacy leaks.

Two studies focus on app use in Europe. Montagni et al. [45] use surveys to study the knowledge, attitudes, and beliefs of French health care students towards France's centralized contact tracing app. They found few healthcare students had downloaded the app, and even fewer were still using it by the time of the study (October 2020); their results suggest that this low adoption was due to concerns about the app's uptake level, lack of interest, and distrust in the app's data security. Also in October 2020 and in Europe, Bosco et al. [5] analyzed tweets about the Italian decentralized contact tracing app Immuni and interviewed 11 app users (as well as 9 non-users) of the app. They highlight that the Italian app does not send reminders to users to check the app for exposures and find that privacy concerns and concerns about app update were barriers for those in the study who had not installed the app. In our work, we study users of a decentralized contact tracing app in Northern Europe – Belgium's Coronalert – significantly further into the pandemic: six months after Coronalert was released. Such further and later exploration is necessary to understand how users evaluate the app's effectiveness as part of their ongoing use of the app, since this is a key concern introduced by prior work studying people's hypothetical motivations for installation and actual use. Such knowledge will help to understand how to communicate this information to the users through the app or other channels. In addition to exploring effectiveness perceptions, we build on these prior works to more deeply probe people's actual use cases for contact tracing apps, their experiences after exposure notification and/or testing positive for COVID, and their mental models in order to distill potential design and marketing directions for future iterations of contact tracing apps, particularly in a European context.

Four studies focus on contact tracing app use outside of Europe. Saleh et al. [51] score the usability of Jordan's contact tracing app, finding it quite high, while Suh and Li [55] explore how negative emotions impact people's use of contact tracing apps in South Korea. More closely related to our work, Tretiakov and Hunter [57] examine people's experiences using New Zealand's contact tracing app in October 2020, five months after it was released. They find that a desire to help support collective health was a key motivator for users to install the app, but that they continued to use it only so long as the pandemic was salient in their mind. In December 2020, Jamieson et al. [34] used surveys and interviews to study attitudes of both app users and non-users about installing and using Japan's contact tracing app and what risks people perceived to app use. They find significant anxieties around interpersonal privacy, being overwhelmed by information about COVID if they were to download the app, and the invisibility of app use (that it was not apparent to others that they were helping in the battle against the pandemic).

Building on these prior works, we focus specifically on contact tracing app users, their use cases, use experiences, and mental models. We conduct our examination significantly further into the pandemic – when the salience of the pandemic may have significantly decreased [57] – to understand how use experiences have changed as the pandemic has continued to progress through waves. Previous studies were conducted up to nine months following the start of the pandemic, ranging between April to December 2020. However, as the pandemic situation progresses, and it becomes people's routine, their pandemic-related attitudes, as well as their app use, may change. Therefore, there is a need to explore how people are using contact tracing apps also at a later point in time, as we do in our study.

## 3 METHODOLOGY

In this section, we describe our methodology and analysis approach, and conclude with a discussion of our approach's limitations.

### 3.1 Background: The Coronalert app

Coronalert is a decentralized proximity tracing app, the design of which is based on the DP3T protocol [58] and the Google Apple Exposure Notification Application Programming Interface.[1] Based on a daily generated random key, the app estimates whether a user has been for a sufficiently long time sufficiently close to an infected user. If so, the app displays a low (in case of shorter than 15 minutes or farther than 2 meters) or a high risk and the number of days since the last exposure; in case of a high risk, a notification also appears on the phone. For a high risk, the user is instructed to quarantine, to consult a general practitioner and to get tested;[2]

The Coronalert app does not contain any identification data, yet to make it more useful results of all tests can be received in the app. This implies that prior to the test, the test has to be linked to the app through pseudonyms. The app generates a random 17-digit code; the testing center copies the user's code and enters it in the testing database that contains patient data and test data; once the result arrives in the testing database, it is transferred to the pseudonymous results database, where it is indexed by this 17-digit code. The app then polls anonymously the results database for a test result corresponding to this code and shows the test result to the user. For positive test results, users are required to confirm sharing their result. Therefore, an authorization code is generated and allows the user to upload her keys in the central database; this code is not visible to the users. As some testing centers had problems entering this 17-digit code [9], a web interface allows users to directly enter the Corona Test Prescription Code (CTPC, a 16-digit government issued code), the 17-digit code from the app, and the national ID number in a web interface. For most users, this turned out to be too complex. From November 2020 on, an SMS was sent to all users for which the test was not linked to their app. This SMS allows users to open a web interface that prefills the CTPC code, takes the 17-digit code from the app, and only requests the users to supply identification data, specifically their national ID number. To encourage participation, from June 2021, users were also able to call a hotline and receive directly an authorization code that they could enter in the app.

### 3.2 Recruitment

Participants were recruited from April-June 2021, approximately a year after the first lockdown order went into effect in Belgium on March 17, 2020, and approximately half a year after Coronalert was launched in Belgium in October 2020. We recruited participants through several channels. On the campus of KU-Leuven (KL), Belgium's largest university and which created the technical design for the national Coronalert app, we (1) placed a physical flyer at the university COVID-19 testing center and (2) distributed the survey through colleagues and local social medial channels, such as Facebook groups. To reach the broader Belgian population, we used (3) an external recruitment service (Cint[3]) to recruit potential participants and also (4) posted advertisements in Belgium's Reddit community (r/belgium) and Belgian Facebook groups dedicated to research participant recruitment (e.g., VUB experiment participant pool, Je fais avancer la science en passant des expériences rémunérées à l'ULB). Ultimately, we recruited nine participants through the university advertisement channels and four through our other methods.

Participants completed an online screening survey as part of their recruitment. While 532 people in total reached our screening survey, only 225 of them provided their email addresses to schedule a follow-up interview. Of those who provided their emails, only 14 people responded to the 64 emails we sent out, an overall response rate of 22%. However, when we reached out to participants outside of KL, the response rate was only 7%. Moreover, recruiting participants who tested positive was even more challenging, with only 16 potential participants reporting that they tested positive and, while we contacted all of these participants, only four participated in an interview.

[1] https://www.google.com/covid19/exposurenotifications/ and https://developer.apple.com/documentation/exposurenotification

[2] From late October to early December 2020 insufficient testing capacity was available and the advice to get tested was restricted to users with symptoms.

[3] https://www.cint.com/

Table 1. Participant Demographics

| ID | Age | Gender | Highest education level | KU Leuven student \employee | COVID-19 tested positive |
|---|---|---|---|---|---|
| P1 | 21 | Woman | Secondary school | Yes | No |
| P2 | 23 | Woman | Bachelors or above | Yes | No |
| P3 | 24 | Woman | Bachelors or above | Yes | No |
| P4 | 31 | Man | Bachelors or above | Yes | No |
| P5 | 23 | Woman | Bachelors or above | Yes | No |
| P6 | 36 | Woman | Bachelors or above | No | No |
| P7 | 24 | Woman | Bachelors or above | No | No |
| P8 | 28 | Woman | Bachelors or above | Yes | No |
| P9 | 32 | Man | Bachelors or above | No | Yes |
| P10 | 24 | Man | Bachelors or above | Yes | Yes |
| P11 | 24 | Man | Bachelors or above | Yes | Yes |
| P12 | 28 | Woman | Bachelors or above | Yes | Yes |
| P13 | 26 | Woman | Bachelors or above | No | No |

The screening questionnaire included a consent form for the study (both the screening questionnaire and the interview study, if selected), as well as questions about participants' Coronalert and COVID-19 related experiences and their demographics. Specifically, we screened for participants who had the Coronalert app installed. We also asked participants other Coronalert-related questions such as whether, since installing the app, they received notifications through the app, whether they got tested for COVID-19 while they had Coronalert installed, and if tested, whether (1) they linked their test result to Coronalert and (2) they tested positive. The latter question was asked because we aimed to recruit some participants who tested positive to understand their experiences with deciding whether to allow Coronalert to notify others that they had been exposed. See Appendix A for question wording. Finally, potential participants reported their demographics: age, gender, education, employment, income, and academic discipline if relevant. Table 1 provides a summary of the participant demographics.

Most of our participants were young educated women, with academic backgrounds including engineering (4), social sciences (3), law (2) and others (4). Furthermore, most of our participants were students (10), 8 of whom were students at KL. Students at KL were able to get tested specifically at the university testing center, however this level of access to a testing center was similar across the Belgian population: at the time Coronalert was available, free PCR testing was easily accessible to the whole population. During October 2020, when the app was launched, approximately 3.67% of the Belgium population was tested each week [53]. That said, we find through our research (Section 4.2.2) that the university testing center was far more consistent in asking for the code needed to link test results to the Coronalert app, perhaps due to involvement of KL faculty, although not the testing center specifically, in the development of the app. This consistency was not known prior to the study nor did it result from a university-specific effort and thus is a finding from this work.

## 3.3 Protocol

Eligible participants were invited to participate in a maximum one hour (mean = 46.92 minutes, STD = 8.83 minutes) semi-structured interview via Zoom or other video platforms. All interviews were conducted in English, a language spoken by approximately 60% of Belgium's population [18]. Participants were compensated with a 20€ Amazon gift card for their participation.

The interview protocol mainly covered the following high-level topics. Please see Appendix B for the full protocol.

- Background questions. Participants were asked about the general use of their mobile phone including questions about Bluetooth: e.g., whether they are familiar with the term "Bluetooth," and if they usually have it turned on.
- Coronalert use. The participants were asked about their typical use of the app and their use as a response to specific cases, e.g., receiving an exposure notification or getting a COVID-19 test. We also queried their motivations for their use of the app and their willingness to take part in the contact tracing process, e.g., to link their test results, if applicable, to their app.
- Mental models. We sought to elicit participants' general understanding of Coronalert. Specifically, we asked participants to draw a diagram or a picture of how they think Coronalert is able to notify them about an exposure. We prompted them, as needed, to elaborate on what information the app would need to give them these notifications and investigated how they thought the app acquired this information.
- Perceptions of and attitudes toward Coronalert. We asked about participants' motivation to adopt the app and their perceptions of the app's effectiveness.

### 3.4 Analysis

The interviews were audio and video recorded. The recordings were transcribed by a transcription service. Two of the authors then discussed the initial set of codes and independently coded the first six interviews, while continuing to recruit more participants. These six interviews were coded iteratively: after coding two interviews at a time, the researchers discussed their findings and updated the codebook and the previously coded interviews. The first six interviews included participants both from KU-Leuven and outside the university. Most of the codes were established at this early stage of the analysis. Using the codebook developed from this process, the researchers independently analyzed the remaining interviews, while updating the codebook. Updates were required after interviewing users who tested positive for COVID-19 and experienced the phase of sharing (or not) their test result through the app. We conducted interviews until we reached saturation and new codes were not yielded from the data. Saturation was reached after coding the 13th interview, at which point we stopped recruiting. A comparison of the codes was conducted using the ReCal2 software package [23] and the researchers achieved an average Krippendorff's $\alpha$ of 0.77, which is above the suggested threshold [43].

### 3.5 Limitations

There are several limitations in our study. We conducted our interviews in English, a language that not all people in Belgium speak. As detailed is Section 3.2, we encountered recruiting challenges, possibly due to COVID-19 fatigue and people's tiredness of discussing the topic. Throughout the recruiting process, we made sure there were no technical issues that prevented participants from providing their emails. Our language constraint, combined with these recruiting difficulties, may have led to our sample bias toward educated young females, with many of them students at KL. These limitations should be taken into consideration when interpreting our results. For example, some of our results might be specified to students, such as experiencing social interactions that are more common among students, like gathering often, as described in Section 4.1.2.

Thus, while saturation was reached, it is possible that a more diverse sample, for example, including less educated and older participants, might have resulted in reaching saturation after interviewing a greater number of participants. For example, Bente et al. [4] found that less-educated participants had more difficulties in understanding aspects related to the app's notifications and key sharing. As a result, we cannot make claims about all Belgian users and their experience with the Coronalert. Rather, our work allows us to provide qualitative themes that were raised by our participants, revealing their perceptions and everyday use of the app. Throughout the paper, we highlight that our results are based on our sample, and are subject to the limitations mentioned. To generalize our findings, and to provide new insights beyond them, a large-scale questionnaire could be developed based on our findings.

Finally, our study design, in which participants were asked about their use of Bluetooth at the beginning of the interview, might have affected their responses at the later stages of the interview. Possibly, some participants mentioned Bluetooth as an essential component to ensure the app's proper functionality as a result of discussing it earlier.

## 4 RESULTS

In this section, we detail our findings, primarily referring to how our participants used Coronalert, including both routine and event-triggered use. Additionally, we report on installation considerations, and on issues related to Coronalert's efficacy, including both participant behaviors related to the app's functionality and participants' perceptions of the app's effectiveness.

### 4.1 Coronalert Installation and Use

*4.1.1 Installation.* Our results support previous findings about users' reasons for initially installing the Coronalert app. For example, we find that social influence has a positive effect on COVID-19 app adoption, with a few participants (3) mentioning they were influenced by acquaintances, friends, and family [6, 16, 19, 34]. Adding to existing knowledge, we revealed a motivation that was not documented in prior work, in which P10 installed the app to receive his COVID-19 test results as soon as possible. P10, a student at KL, was motivated to install the app after he learned about it while getting a COVID-19 test:

> "And when I got tested there [KL testing center], they asked me: do you have the app? They advised me to install the app. ... For me, the sooner you get to know your test results, the easier it is for me. So that was the main reason for me."

For P10, as we learn from his response, the main function of the app is to serve as a "testing app," rather than as a contact tracing app; we will discuss this use of the Coronalert app further in Section 4.1.2.

*4.1.2 Use.* Once they installed Coronalert, participants described various ways of using the app. Broadly speaking, we observed two types of Coronalert use: "active" use, in which participants opened the app on a regular basis to track their exposures or to view statistics about Belgium's COVID-19 current situation (10 participants); and "ad hoc" use (3 participants), in which participants did not actively open or check the app but had the app installed and opened it when they felt it necessary, e.g., when they received a high-risk push notification, or for testing purposes.

Many active users (8) reported that at the time of the interview, they were using the app less frequently than when they first installed it. However, most (7) were still actively using it. Participants' explanations for the change in their use were mostly related to the changing pandemic situation. Specifically, some (5) participants explained that at the beginning, the COVID-19 situation was new, exciting and frightening, which motivated people to actively use the app. However, as the pandemic proceeded, the situation had changed, and participants mentioned cognitive (5) and functionality (4) reasons for actively using the app less frequently.

Cognitive reasons reflected "general fatigue" toward the pandemic (P9), or desire to escape the situation to some extent, as expressed by P1: "I try to stay optimistic." These explanations are in line with the perceived general atmosphere, as described by our participants, at the time of our interviews: multiple participants thought that people are "tired of rules" (P7) and unmotivated to follow them. Regarding functionality, participants had several reasons to use the app less, including lower exposure risk (2) and a low trust in the app's effectiveness (2). Two participants explained that their COVID practices at the time reduced their exposure risk. For example, P7 explained that her behavior had changed in a way that "in general, [I] don't come outside a lot anymore." See Section 4.2 below for further discussion on the app's efficacy.

*Use #1: Statistics.* Eight participants mentioned viewing Belgium's COVID-related statistics as one of the main reasons to open the app regularly. Keeping the app relevant, P9 was pleased about a recent update in the app, which also provides general information about the vaccination process.

*Use #2: Exposures.* As previously mentioned, some participants (8) actively checked for exposures, tracking their low-risk ("green") and/or high-risk exposures ("red"), while others (3) only opened the app if notified on the phone's screen, which only occurs when Coronalert detects a high-risk exposure (see Section 3.1).

Participants who actively tracked their exposures shared a variety of reasons for doing so. For example, P13 explained that she was nervous about the virus and wanted to know if she had exposure risks. P2 explained that she used the app to compare her personal exposures with the general population exposures by comparing her exposures and the reported daily infections for her area. This comparison fulfilled two goals: the ability to have a perspective of her exposures compared to the country's situation, and to evaluate the app's ability to track her exposures. Moreover, she explained that, at least at the beginning, she was socially motivated to open the app regularly:

> "In the beginning when the numbers were rising, in our friend group it was often like: oh, no, my Coronalert was red, or my Coronalert was this and that. So we actively used it in our friend group, at least."

Three of our participants were notified about a high-risk exposure by Coronalert, six experienced a low-risk exposure notification, and four participants did not have any detected exposure to COVID-19. Describing their feelings about low-risk exposures, two participants were a bit scared when the exposures first appeared on their app, "slightly more anxious," as described by P9. Two participants looked for further information, by either reading or asking a friend, about the meaning of this type of exposure, whether, for example, "Do I need to do anything with it?" (P5). P2, who experienced both low- and high-risk exposures, expressed a mental model in which she distinguished between the reasons for the two types of the exposures:

> "Then in [a] case that [a] person would be tested positive, then I would get an alarm or like an exposure. And then depending on how long the time and the distance was, it can be like a green exposure or a red alarm."

Of those who were notified of low-risk exposures, three participants either took steps to gather more information about the notification, or expressed their desire for extra information about their exposures. While P9 was able to view the relative timing of the exposure – the app shows the number of days since the last exposure – for P6, the information was not detailed enough. The missing information disturbed her, as it prevented her from understanding how she may have been exposed. For P8, a lack of additional information raised questions about the app's reliability:

> "I wonder a bit sometimes because I don't leave the house a lot. So I wonder where the green ones even come from sometimes."

Participants who were notified about a high-risk exposure (P2, P12, P13) described the steps they took after they were notified. All three participants decided to quarantine after receiving the notification, and P2 also got tested. P13 was worried when she was notified and decided to mostly follow the recommendation to quarantine. However, she also explained that she was already staying at home at that time, therefore, going quarantine was not much of a difference for her. She later shared that she is not sure whether she would have acted in the same way if she was notified these days (at the time of the interview), as she has resumed working outside the home and her regular activities:

> "If you get the notification, you can't say, well, I'm not going to work for two weeks and just let's see what happens. Not everyone can do it. So the reaction to the notification depends really on the person."

Similarly, P12 also self-quarantined. However, she actively investigated the source of the high-risk exposure by contacting people with whom she had recently interacted. Despite her conclusion that her exposure was probably a false alarm, she still decided to quarantine. She described her reaction:

> "I was really contacting everybody who I had contact with [to understand why I was notified]. And I couldn't find somebody that was close to me, and that was tested positively. So I was thinking rationally it should be a false alarm... we [another friend who was notified] figured out that both our cell phones were in the same locker compartment, and it was probably there that we got the red screen."

P2 was aware of a close contact she had. Therefore, when her screen turned red, she was excited to find that the app worked: "So I was really like, Whoa, this works. This is cool." Similar to other participants, she also described the process of self-determining the source of her exposure, considering both her low and high-risk exposures, and what contact eventually resulted in high-risk notification.

*Use #3: Testing.* Almost all the participants (12) were tested for COVID-19 at some point after they had installed the Coronalert app. All participants were willing to use the app during the testing process. Two participants referred to using the app for testing purposes as their main use of the app, although in practice, one of these two participants (P10) used the app nearly daily. P4, the other participant, explains that he engaged with the app exclusively for receiving his test results.

Overall, participants mentioned three main motivations or influences that brought them to use or want to use the app as part of the testing process: ease and speed of receiving the test results (9), informing others (6), and because they were requested to do so by the testing center (3).

Many participants (9) were motivated to register their COVID-19 test with the app because it was easier and quicker to receive their test result through Coronalert. For example, participants mentioned the app as a better solution to get the results since it allowed them not to "call somebody" (P1); "wait for the email" (P11); or to "navigate the Belgium healthcare system" (P8). Some participants (6) registered their COVID-19 test with Coronalert in order to inform other people if they tested positive for COVID-19, and thereby help fight the pandemic. For example, P6 thought it was a "moral obligation" and that the option of *not* registering the test is "very, very strange." Few other reasons were mentioned for registering the test, such as keeping one's anonymity by not having to notify contacts personally that they were exposed (2) and "Why not?" (1).

Four participants in our study had tested positive for COVID-19. While all four expressed their willingness to share the results through Coronalert, only two of them (P9 and P12) did so in practice. While both P9 and P12 contacted people in person to inform them that they were at risk, P9 also referred to the advantage of using the app. He appreciated the apps' ability to inform a greater circle of people since "you never know, especially if you're outside and you're just cross some people." P12, on the other hand, criticized the lack of information provided by the app about the situation, preventing her from deciding if it was a real high-risk case or not:

> "But to me, it shouldn't be anonymous, it would be nice to know that person on depth, or, like at least get a notification about the hour and location, not the identity of the person. Because then you can realize, okay, I was at the supermarket, that's not a high risk thing. "

The two remaining participants who tested positive did not share their result. P11 had a technical issue, and P10 was not aware of the option to approve the sharing of his result. P10 found out about it only during the interview, echoing a news report about this issue [9]: "I just got the results, and it didn't really ask me anything more." P11 answered a hypothetical question about whether he would have shared the result if he had been able

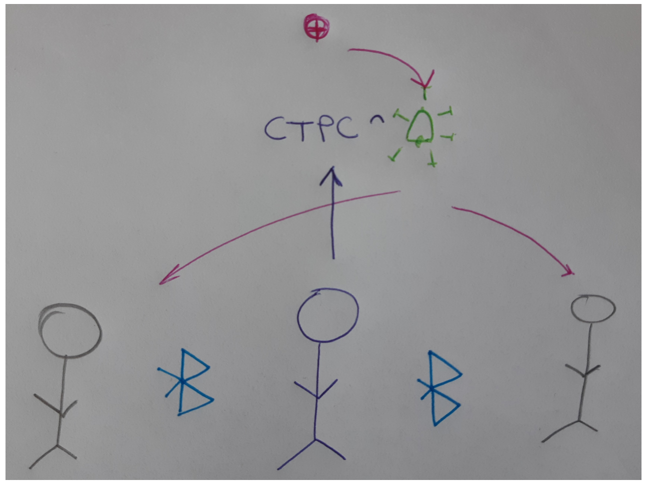


Fig. 1. Participant P5's drawing of their mental model of the Coronalert notification process. When explaining this drawing, P5 mentioned Bluetooth as the required technology to detect proximity: "So we're connected through Bluetooth."

to do it. Beyond his positive willingness to share his result, he also highlighted his expectation to automate this process. He found it confusing to manually take an extra action to share the results with his contacts.

## 4.2 App Efficacy

In order for the app to offer the benefits participants seek, they must use the app correctly, and it must function correctly. First, to track exposures, users' Bluetooth must remain on when they are out and about. Second, users must register their COVID-19 test with the app and, in positive result cases, must actively confirm that they agree to share their test result. Lastly, enough people must install and use the app as intended (i.e., have their Bluetooth on, register the test, and authorize the app to alert others).

*4.2.1 Bluetooth Use.* It remains an open question whether people actually kept their Bluetooth turned on while they have contact tracing apps installed. Previous works found that users mentioned Bluetooth as one of the reasons to uninstall contact tracing apps due to technical problems or forgetting to enable it [45, 61]. In our study, we find that most participants (10) kept their Bluetooth constantly on. Five participants did so before installing Coronalert since their phone is connected to other devices such as a smartwatch or speaker. The other five participants mentioned Coronalert as the main reason for turning Bluetooth on. The three other participants responded that they usually have their Bluetooth off, and explained that they either forget about it, or turned it off to save battery.

Comparing participants' mental models to their behavior, all participants included Bluetooth as an essential part of the notification process, in most cases (11) explaining that this is how the app detects proximity between phones, for example, as explained by P5 (see drawing in Figure 1):

> "Let's say this is me [pointing at a character in her drawing], and [these are] two people that I've been in contact with. And we all have the Coronalert app. So we're connected through Bluetooth. And that's how the app knows that we've been in contact with each other, because of the signals that go through Bluetooth."

Of the 13 participants, while mentioning Bluetooth, two participants were not sure if it was Bluetooth or something else that was used to detect proximity. Additionally, while P13 mentioned Bluetooth as part of her mental model, she also shared that she previously looked for information about it since it was not clear for her whether the Bluetooth should be on. Another participant, P4, thought that Coronalert needed Bluetooth to work, but thought that the app would turn on Bluetooth automatically.

*4.2.2 Test Registration in Practice - Providing the test code.* In order for participants to allow others to be notified of exposures, or to receive their test results (Use #3), they must register the test so that their test results can be linked to the app. Users could either register their test while getting tested or later. To register the test while getting tested, users provide an "app-generated code" to the medical staff. To register the test at a later point, users could either follow a link sent by a "post-test SMS," or independently use a web interface to link their app to the test. Two of our participants described multiple experiences while being tested. Therefore, in this section, we refer to number of testing experiences described and not to the number of participants.

In nine of the testing experiences participants described, participants were asked to provide the code when they got tested, and in all of these cases, they agreed and provided it. Moreover, it is worth noting that of these cases, participants who got tested at the KL testing center were always asked to provide the code. For example, P2 described the testing process in KL testing center:

> "They asked me there on the spot: Can you generate a code, because then your test result is directly linked also to your Coronalert, and you can see your result there as well. So it was there at the info desk that I generated my code."

In six testing experiences, all of them outside of the KL testing center, participants were not asked to provide the code while getting tested. Of these cases, two participants described incidents in which they provided the app code nevertheless. One of them is P11, who was tested multiple times and provided the code in some cases, but not all. As he explained, based on his previous experience, he knew that he will receive the test results by email. Therefore, since he was mainly interested in receiving the results easily, he did not bother to provide the code in all cases. The second participant who registered the test was P12, who got tested twice. At the first test, she received a post-test SMS with a link to the web interface through which she could link the test to the app. She followed the link and registered the test. At the second test, she did not receive a post-test SMS and did not register the test. She pointed to the need to minimize the effort required to register the test:

> "If it's offered to me, I will accept it and do it, but I will not actively go and look for it. Especially not if I was thinking like, I don't have any symptoms. [P12 was required to get tested for a specific reason]"

Two other participants, who also were not asked for the code while getting tested, did not provide it during testing, nor did they link their tests to the app later. They explained that they either forgot about it, as P5 did, despite familiarity with the testing process as part of her daily work, or did not know how to register the test. P13 received a Cororona Test Prescription Code (CTPC) during the test, but was not sure if she was supposed to enter this code to the app (she was not):

> "I received [a] code. But it was just to have the test. And I didn't know if it was the same code to enter in the app. And then no one told me, show me your app, or do you want to receive your results through the app? No one told me that."

To summarize, in all cases when participants were asked to provide the code during the testing process, they cooperated and provided it. In cases where participants were not asked to provide the code (6), in two of them the participants registered their tests, either as a result of receiving a post-test SMS, or by actively asking the medical staff to provide them with the code. In the remaining four cases, the participants did not register the test at all.

Just because participants provided the code when asked does not, however, mean that they understand why it is necessary to do so. While describing how they think the app works, only five participants mentioned the testing code. In some other cases (5), if not mentioned by the participant, they were directly asked about the code and its role in the process of notifying users. While participants' descriptions of the process were not always accurate, many of them (9) described the code as a way to link the app with the specific user's test result. P6's response is an example of a wrong understanding of the code's role. P6, who was directly asked about the code, thought that it allows health professionals to detect hotspots, in case the user is not willing to share the result.

In sum, most of our participants had their Bluetooth enabled and knew it was necessary to ensure the app's functionality. In two other studies [45, 61], users had complaints about Bluetooth and considered it as one of the reasons to uninstall the app. There are several differences between our study, including the time in which the data was collected (our data was collected approximately six months later) as well as the sample size. Therefore, further quantitative research is necessary to explore users' use of Bluetooth. As for providing the code, we found a strong reliance on the human aspect: participants mostly provided the code only when they were actively asked to do so.

*4.2.3 Effectiveness Perceptions.* Regardless of whether they used the app in ways that allowed it to be effective, participants had their own overall perceptions of whether the app effectively achieved their goals. Participants expressed their perceived ineffectiveness of the app in several contexts. For example, seven participants thought that the app did not play a significant role in fighting the pandemic due to limited app adoption across the entire population. For the same reason, two participants thought that they were unlikely to be notified by the app even if they are exposed, as expressed by P11: "[I] don't rely on it much." This result is in line with other works reporting on similar users' perceptions [5, 45, 46, 61]. Other reasons for considering the app ineffective were as a result of a personal experience, in which, for example, two participants explained that they received few or no notifications from the app, which they deemed unreasonable.

## 5 DISCUSSION

This work aimed to investigate how people use contact tracing apps and their motivations for how they use these apps. We interviewed 13 young adult users of Belgium's contact-tracing app, Coronalert, approximately a year after the COVID-19 pandemic had started, at which point the situation was "not so new anymore" (P2). We find that some of our participants repurposed Coronalert from a contact tracing app into a testing app. Our results highlight the trade-off between keeping users' privacy – through minimizing data collection as much as possible – and users' desire to have *more* detailed information which would rely on greater data collection, to make better-informed decisions. Based on our participants' responses, we propose a framework that specifies users' decision-making points in contact-tracing apps (Figure 2). We then summarize our participants' mental models of how Coronalert works and the implications of these understandings, suggest strategies for maintaining long-term use of such apps, and review the role of privacy in digital contact tracing.

### 5.1 Framework of Decision Points in People's Contact Tracing App Use

Many prior works explored people's intent to install contact tracing apps [24, 37, 41, 48, 54, 63]. While these explorations are essential to increase adoption, which is necessary for efficacy, adoption is not enough on its own. By studying how people actually use contact tracing apps, we can identify additional points of failure or risk in the app life cycle. Building on our findings and the prior work on app use in other countries reviewed in Section 2, we propose a model of human factor decision points in the use of contact tracing apps (Figure 2). First and foremost, people must **install** the app. Once installed, users must have their **Bluetooth enabled** to ensure the app's functionality [61]. Next, to enable the app's contact tracing functionality, the users need to **register their COVID-19 tests** and **authorize the app to alert others** in the cases of positive results [6, 34]. In Belgium, as of February 2021, only 37% of Coronalert users who had tested positive authorized the app to share their result, and this percentage was dropping [8]. Lastly, for the app to benefit public health by reducing infections, users need to respond to exposure notifications by following the quarantine and testing recommendations.

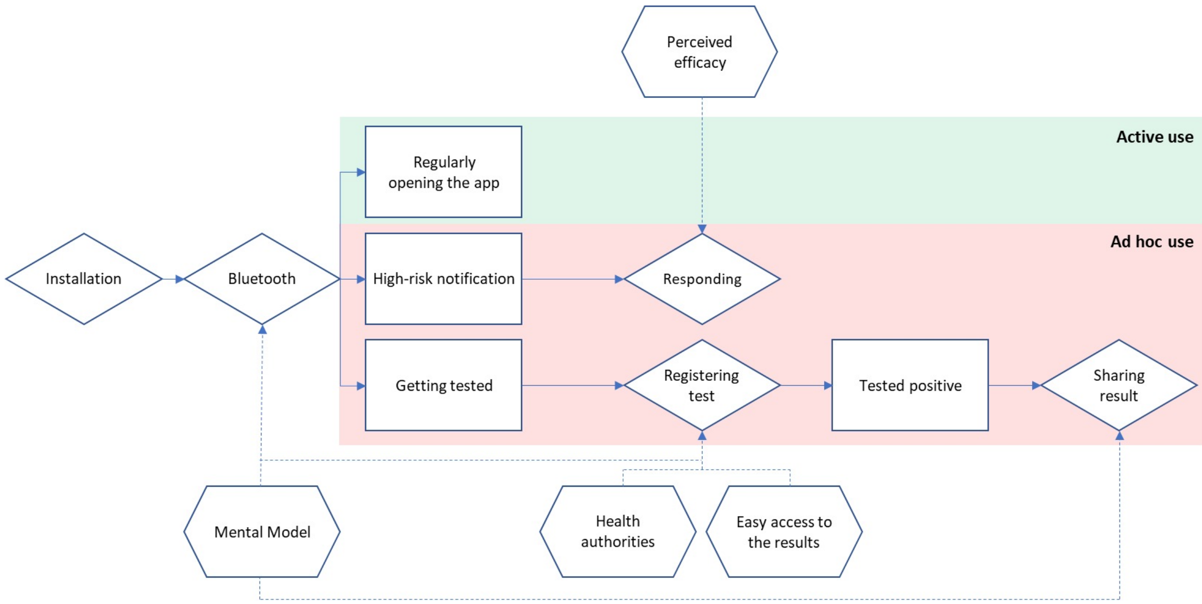


Fig. 2. Framework diagram illustrating the decision process of using the Coronalert app. The rectangles represent events (e.g., getting tested, receiving an exposure notification), the diamonds represent a user decision (e.g., to open the app, to turn on Bluetooth), and the hexagons represent influencing factors (e.g., mental model of how the app works).

Therefore, we explored the users' **response to exposure notification**. Lastly, more broadly and not as a specific decision-making point, we refer to the need to **keep the app installed**, which is not a trivial task. In Scotland, for example, approximately a year after the Protect Scotland app was launched, fewer than half of the people who had downloaded the app were actively using it [3]. Relatedly, we refer to users' **use of the app on a regular basis** [57], including using it as an information source [50], and not merely as a contact tracing app.

## 5.2 Users' Mental Models along the App's Decision Points

We find that, broadly speaking, our participants demonstrated correct mental models about how Coronalert works. However, they had misunderstandings of some of the app's functionality, which reduced their ability to use Coronalert effectively. For example, wrong mental models resulted in (1) keeping Bluetooth turned off in one case, and (2) not authorising the app to share a positive test result in another. In these examples, the app was not able to perform its main objectives: (1) contact-tracing and (2) notifying others. In this section, we follow our suggested decision points framework to examine possible pitfalls resulting from the participants' mental models.

*5.2.1 Bluetooth.* Most participant had their Bluetooth on when using Coronalert, and when asked to describe how the app works they correctly described that Bluetooth is the technology used to detect proximity to other Coronalert users. However, not all participants had this understanding: two participants were not sure if Bluetooth, or another (unspecified) technology, was used to detect proximity. Additionally, one participant incorrectly thought that Coronalert would turn on Bluetooth automatically when needed. To overcome such misunderstandings, steps should be taken in several direction, including (1) educating the general population about the app's basic requirements; and (2) timely warnings. In Belgium, both directions were taken, using (1) media channels to explain about Coronalert, and (2) if the Bluetooth is off, users are notified on their phone screen that the Coronalert app is currently unable to work and that an action - turning their Bluetooth on - is required. However, we observe that these notifications are sometimes missed by the users. Thus, more steps are required to ensure users' understanding, for example, by using an interstitial (blocking) notification to get users' attention when they open the app and to prevent them from proceed before reading a concise notification about the Bluetooth requirement, as is done in other settings such as for digital account security [28].

*5.2.2 Responding to Notifications.* The majority of participants understood what to do when they received different kinds of notifications: for high-risk notifications, participants followed the recommendations at the time and quarantined, and for low-risk notifications, they did not take further actions. While no action was supposed to be taken as a result of low-risk notifications, our participants used them for a variety of purposes including using it as a reference to compare their exposures with those reported for the general population. Despite most participants understanding the necessary actions to take for a given notification type, two participants did not know what to do when they were notified about low-risk exposure. Thus, for clarity and to help reduce anxiety when possible [34, 55] (as low-risk notifications represent low-risk), contact-tracing apps should clearly explain the meaning of notifications, and what actions are expected of the user, if any.

*5.2.3 Registering a Test.* Less than half of our participants mentioned the app's generated code as a piece of necessary information to ensure the app's proper functionality. Registering the test using the app code is a crucial point from the app's functionality perspective. We refer to this decision point in more detail in Section 5.5.

*5.2.4 Sharing Positive Results.* Users are required to authorize the app to notify others about a high- or low-risk exposures in case of a positive test result. However, only 37% of users nationally – and two out of four participants in our study – do so [8]. One of our participants (P10) did not know that he was supposed to actively approve sharing his test results, and another participant (P11) expected this process to be automated. This crucial decision-making point is an example in which an option for a one-time consent might be useful: where users are given the option to confirm their general agreement to warn others anonymously in case of receiving a positive test result at the time they install the app vs. upon the occurrence of each positive case. Such one-time consent can reduce friction. However, more research is necessary to ensure that such a change would not severely violate people's privacy preferences.

## 5.3 Maintaining Long-term Use

Participants used the app in different ways and were motivated by various reasons, of which willingness to prevent the infection of others was only one. The ease of receiving test results through the app was considered very useful, to the point of repurposing the app into a testing app. Participants also spent time using the app for other reasons, including regularly opening the app to track Belgium's COVID-19 situation and actively checking whether they had low- or high-risk exposures. People's interest in receiving crisis information has been documented both in the context of COVID-19 [50, 55], and during crises in general [21, 30, 31]. For example, Grinko et al. [30] found that people considered "relevant, reliable and up-to-date information" one of the main functions of a crisis app.

The secondary functionalities mentioned, i.e., using the app for testing and as an information source, do not prevent the app from being used for its primary goal – to notify people about a high-risk exposure. Moreover, in the case of testing, it is essential to use the app during the testing process in order to achieve the app's primary goal. Bundling together several features related to the main topic, in this case the COVID-19 pandemic, might prevent users from uninstalling the app. Previous work has found that users mainly uninstalled contract tracing apps because they drained the phone battery [45, 56], were perceived as ineffective due to insufficient amount of people using it [45], or competed with another contact tracing technology [56]. As observed, some of these reasons point to technical problems. While secondary functionalities are not a replacement for the app's primary purpose, our results point to the benefits of including and promoting such additional features in the app. These additional features might reduce the uninstallation rate by raising the perceived usefulness of the app for purposes other than merely contact tracing, and by creating a long-term relationship. In previous work, when asked to evaluate the Italian app, users complained that it is useless for them to open the app on a daily basis since the app does not provide additional information [6]. Our observation, on the other hand, highlights the success of offering secondary functionalities. Similarly, updating existing features, such as adding information about the vaccination process as the situation changes, or using existing features for other purposes, such as using the app as a personal diary in general [57], may also encourage long-term use.

As we observed, our participants reduced their frequency of using the app over the pandemic period, partially as a result of a general fatigue. A similar phenomenon was observed in New Zealand, in which participants changed their behavior based on the pandemic severity level [57]. Our observation adds to previous work by highlighting the accumulated effect of the continuous, disturbing situation on users' use of the app. However, despite the observed reduction, our participants did not decide to uninstall the app completely. Previous work found that challenge emotions, such as anticipation and hope, increase the likelihood to continue to use the app [55]. In our settings, in which general fatigue was prominent, we point to in-app aids, such as adding secondary functions and updating existing ones, as a possible way to overcome external difficulties, and bring the user to keep using the app as "part of the habit to have it." (P11)

## 5.4 Privacy - to What Extent?

The Coronalert app, similar to other contact tracing apps that use the Google/Apple Exposure Notification (GAEN) system, was developed to allow contact tracing while also preserving its users' privacy. To reach this goal, only the minimum required data is collected and, accordingly, revealed to other users in case of exposure. Previous works find mixed results about the role of privacy concerns in people's adoption and use considerations of contact tracing apps. While some point to privacy concerns as one of the factors that hinder people from installing contact tracing apps [26, 37, 38, 41, 48, 54, 56, 62–64], others suggest that privacy is less important than other considerations like trust [33] and a desire to join the fight against the pandemic [57]. Our findings suggest that these differences in findings may be the result of users making a trade-off between their perceptions of the app's privacy and its usefulness from the users' perspective. Some of our participants described their desire to know more about exposure incidents, including when (in a higher resolution than a day) and where they were exposed, particularly when they were notified about a high-risk exposure. Participants explained that knowing more about the exposure would allow them to decide if they consider it a high-risk exposure. Others mentioned it as a way to evaluate the app's accuracy, allowing them to identify false alarm cases, for example, due to proximity to neighbors' apartments. Similarly, in New Zealand, participants suggested improvements for the app, in which the suggested design was less privacy-preserving. In this case, the participants preferred the app to automatically collect users' location data, as opposed to manually scanning QR codes [57]. In both studies, the consequence would be a more useful app in terms of decision-making and usability, at the cost of a more invasive app.

Our results show that different individuals have different perspectives on privacy. While some of our participants thought that more information about the exposure should be revealed, and therefore collected, others mentioned the app's anonymity as a motivation to register their results. Moreover, Coronalert's privacy-preserving architecture might have influenced our participants' responses and willingness to share their test results. When explaining why they would register their test, only three participants mentioned privacy-related issues, and they all positively referred to trusting the app and its anonymity. The remaining participants, who did not mention privacy, possibly were either not concerned about it in the first place, or rectified their concerns at the time of installation. Therefore, in the context of registering their test, privacy was no longer an issue - since they already decided that the app was keeping their privacy appropriately. A similar explanation was suggested for why privacy concerns were not found to be related to uninstalling contact tracing apps [56]. Prior works find that users' decisions whether to participate in the contact tracing process or not is influenced by both privacy considerations and social context. In some studies, where the explored apps were privacy-preserving, i.e., decentralized, privacy concerns were sometimes prominent (Japan) [34], or not (Italy, New Zealand) [5, 57]. In these cases, when hesitating whether to use the app, users either expressed privacy concerns despite the app's architecture (Japan) [34], or were concerned about other aspects, such as fear of unnecessary quarantine (Italy) [5]. In another study, in which the explored apps were considerably less privacy-preserving, users indeed expressed privacy concerns (South Korea) [55]. The South Korean apps are more invasive than the Coronalert and similar apps for several reasons, including their centralized architecture, collection of location data, and disclosure of personal information, such as age and gender.

Taking our and previous studies' results together, we find support for our hypothesis that the Coronalert's privacy-preserving architecture was helpful in encouraging registering test results. Privacy concerns were prominent when the app was more privacy-invasive, as in South Korea [55]. However, as seen in the Japanese app case, a privacy-preserving app is not enough on its own to encourage installation and use, pointing to the effect of the social context in which the app operates [34]. Further, our study reveals a complicated situation in which, on the one hand, users express their willingness to accept an app that is less privacy-preserving to make more informed decisions and increase perceived reliability. On the other hand, compromising privacy to a certain extent, as done in South Korea, might hinder people from installing it in the first place and reduce their willingness to register their tests as a result of privacy concerns.

### 5.5 Involving Health Authorities when Designing a Health Technology

For a tracing app to work effectively, users must register their COVID-19 tests, either while getting the test by providing the test code to the medical staff or by using a dedicated website afterward. Our results point to a strong influence of the testing process on test registration. When participants were asked to provide their anonymous identifier code as part of the testing process, as was done in all cases when participants got tested in the KL testing center, they agreed and provided it. In contrast, in only two cases out of six did participants register their test if they were not asked to by the medical staff, similar to the 37% test registration rate reported across Belgium [8]. Participants either forgot about registering the test, did not know how to do it, or knew that they would receive the test results in a different way and thus did not bother.

There are several lessons that can be learned from our study findings, which were elicited by comprehensively exploring how the app's registration process was designed and executed by our participants. As already discussed, this process involved the integration of the app with the local health authorities. In a study that explored the Italian app, users were concerned about whether the operators would know how to insert the code, but in a later stage of that study, this issue was reported as not problematic from the medical staff perspective [5]. In The Netherlands, a simulation of a phone call from the health authorities was conducted to learn about the key registration process [4]. Based on the simulation, the authors discussed the need for the health staff to be well-prepared to help the app users during the process. Our study, with its "in the wild" setup vs. a lab study [4], and its focus on the detailed use vs. attitudes [5], reveals new insights beyond these findings.

The Coronalert app was originally designed to require the involvement of the medical staff. However, as we observed in practice, the process did not always include a request to provide the code, in many cases resulting in not registering the test altogether (i.e., neither during the test nor afterward). Our results, as well as previous works in health technologies, point to the need to involve all types of users, including medical staff, when designing a health technology [12, 17, 29]. For example, these works call for considering the influence of the technology on the medical staff, such as influencing the staff's required skills [29] and their workflow [12]. These issues, as well as the medical staff's willingness to take part in the process, should be considered. The case of the Coronalert app highlights both the need to involve medical staff during the design phase to learn about their preferences and abilities, and the need to "decentralize" the responsibility to register the test. The app's design was updated in a later stage to allow users to also register the test by themselves, and not only by the staff (see Section 3.1).

While it was theoretically a good idea to provide users with the ability to register the test by themselves, in practice, we found that when they were not explicitly asked to do so, they did not register the test in most cases. Our participants were willing to register their test, and at least for some of them, their mental models pointed to the understanding of the code's role in linking their app to the test. However, despite their willingness to participate and to provide the test code, several usability problems prevented them from doing so in practice. For example, users forgot to provide the code while getting tested if they were not asked for it. Similarly, forgetting was a barrier to manually reporting users' locations in New Zealand, in cases where a QR code was not available immediately [57]. A possible solution to the Coronalert situation would be to notify the users through the app while at the testing center, instead of solely leaning on the medical staff. For example, Bluetooth beacons located at the testing center could be used for this purpose. Another reason for not registering the test was a lack of knowledge of how to do it. Similarly, understanding how to actively register the test was a concern also in a design study, pointing to the non-trivial task and the need to provide appropriate support [4]. As with the suggested reminder to register the test, a timely response would be helpful. Possibly, such a response could be either through the app, in which an explanation could appear based on the beacon, or by placing physical explanation posters at the testing centers.

## 6 CONCLUSION

To be effective, users of contact tracing apps need to use the apps appropriately, e.g., have their Bluetooth on, and link their app with their test result if it was positive. While extensive research previously explored people's intent to adopt these apps, less work was done to explore users' actual use of these apps. To narrow this gap, we conducted a semi-structured interview study with 13 young adult users of Belgium's contact tracing app, Coronalert. Our analysis of these interviews resulted in two key findings. First, we found that our participants repurposed Coronalert into a testing app. This finding highlights the potential role of secondary functionalities in maintaining a long-term use, as well as in marketing efforts. Second, our results, as well as contextualizing them with prior work, point to the need to continue to study users perceptions and desired functionality for evolving technologies. In our study's context, we observed the continuous change in our participants' perceptions and attitudes about the pandemic in general, and contact-tracing apps specifically. Thus, continued research is needed on people's perceptions of and expectations for contact-tracing apps.

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## A SCREENING SURVEY - CORONALERT-RELATED QUESTIONS

- Do you currently have CoronAlert app installed?
- When did you install CoronAlert app, approximately?
  - Right when it was released (September 30 - October 31 2020)
  - After the first month of the app launching but more than three months ago (between November 1 2020 and December 31 2020)
  - Recently (between January 1 2021 and today)
- Since the time you have installed CoronAlert , were you notified by the app that you were in close contact with someone who has been tested positive for the coronavirus?
  - Yes
  - No
  - I do not remember
- Since the time you have installed CoronAlert (date added), did you get tested for the coronavirus?
  - Yes
  - No
  - I prefer not to answer
- Display logic: following questions were presented if the participants got tested since the time they installed Coronalert.
- When did you get tested, approximately? If you got tested more than once, please refer to the first test when answering the question.
  - Around the time when the CoronAlert app was released (September 30 - October 31 2020)

  - After the first month of the app launching but more than three months ago (Between November 1 2020 and December 31 2020)
  - Recently (between January 1 2021 and today)
- Have you ever provided the app test code to the doctor/medical professional?
  - Yes
  - No
- Were you ever provided with a Covid-19 Test Prescription Code (CTPC) by the contact center/test center/ medical professional?
  - Yes
  - No
- Have you ever entered the app test code on the CoronAlert website?
  - Yes
  - No
- Have you ever received an SMS that included a link to the CoronAlert website, and provided your national number? The Covid-19 Test Prescription Code and the app test code were automatically filled.
  - Yes
  - No
- This question is optional. You can choose whether or not to share this information with us. Since the time you have installed CoronAlert (date added), did you test positive for coronavirus?
  - Yes
  - No
  - I prefer not to answer.

## B INTERVIEW PROTOCOL

**App related behaviour**

- What type of phone do you have?
- In a typical week these days, would you say that you bring your phone with you when you leave the house?
  - Would you say that this has changed at all over the period of the pandemic?
  - Has this changed at all since you have installed the CoronAlert app?
- Have you ever heard of something called Bluetooth?
  - Do you know if this is something that your phone has enabled?
  - Do you know if you can turn Bluetooth on and off on your phone?
  - If applicable - Do you typically turn your Bluetooth on / off?
  - Has this changed at all over the period of the pandemic?
  - Has this changed at all since you have installed the CoronAlert app?

**CoronAlert Use**

- When did you install the app?
- Could you walk me through how you use the app during a typical week?
  - if not mentioned - Do you open the app?
    - If yes, what do you check when you open the app?
  - Has the way you've used the app changed since you first installed it?
- Have you ever uninstalled the app?
  - If yes - Do you have it installed now? What made you decide to reinstall?
- Since the time you have installed CoronAlert, were you notified by the app? (that you were in close contact with someone who has been tested positive for the coronavirus)

  - If yes - Could you walk me through what you thought and did when you saw the notification?
    * What did you consider doing? Why did you decide not to do this?
      · Did you consider quarantining?
      · For how long? Why for this period specifically? (was it advised by the app?)
      · Did you request a corona test?
      · Did you call a doctor?
    * If was not mentioned before, in the context of test code: Would you say that the actions you took have changed at all over the period of the pandemic?
    * Have they changed at all since you have installed the CoronAlert app?
    * *Decision making - generating the code* (if was not mentioned): Has the app ever prompted you to generate a code (that enables you to get your test result in the app)?
      · If yes - As per your understanding, what does the code do?
      · If yes - Could you tell me a bit more about why you decided to generate it?
      · If not - Could you tell me a bit more about why you decided not to generate it?
- What do you think other people using the app do with it?
  - If not mentioned - Do you think others are checking the app?
  - What do you think they do if they are notified that they have been exposed? If mentioned as part of the walk-through: Do you think others are using the app's test code?
    * In which way? By providing the app's test code to the doctor, or by using the webform, or both?
  - How do you get these impressions about what others might be doing? From the media, private discussions?
- *Decision making - providing the code:* Have you been tested for COVID since you installed the app?
  - When did you get tested?
  - Why did you decide to get tested?
    * Were you notified by the app, phone call from the ministry of health?
    * Were you personally advised by a friend who tested positive?
    * Because you had symptoms, without any notification?
    * Any other reason?
- *Generating the code - asked by the doctor* (if tested): When you got tested did the doctor or medical professional ask for the app's test code? Or, did you ask to provide it?
  - If not - Did you know you could inform the app that you are getting a test while at the doctor/testing site?
  - If yes - People have many different feelings about whether to provide the test's code. What did you decide to do when the doctor asked for the code?
- *Generating the code - via webform* (if tested): Did you register with the app's test code on the CoronAlert web site, together with the Covid-19 Test Prescription Code (CTPC)?
  - If not - Do you know what is the Covid-19 Test Prescription Code? Did you receive it?
  - If not - Did you know you could use the web site to register with the app's test code, even if not at the testing site?
  - If yes - People have many different feelings about whether to provide the test's code.
- *Generating the code - via SMS* (if tested): Did you recieve an SMS with a link to the CoronAlert website?
  - Could you walk me through what you thought and did when you saw the SMS?
  - Did you know you could use the web site to register with the app's test code, and your national number?
  - People have many different feelings about whether to say yes to this prompt. What did you decide to do?
- *Decision making - sharing the results* (if tested): How did you learn first about the test results?
  - How long did it take to get the result?
  - How long did it take to get the result in CoronAlert?

  - If you feel comfortable, would you mind telling me your test result?
  - Could you walk me through what you thought and did when you saw the result in app?
  - If yes, positive, and wasn't mentioned - Did you choose to share the result using the app?
- If not mentioned earlier, as part of the initial walk-through, and responded yes for generated the test code - Would you say that your typical decision to provide your test code at the testing site / register using the activation code has changed at all over the period of the pandemic?

**Mental models of CoronAlert**

- Now, I will ask you to conduct a drawing task. Please draw a diagram or picture of how you think the CoronAlert app is able to notify you about whether you've been exposed to coronavirus? What information does it need? How does it get that information? Please be as detailed as possible and take all the time you need. After you finish, I will ask you to explain to me your drawing
- Follow-up questions: (if wasn't explained)
  - How do you think the app can detect whether you are in close contact?
  - What is required for the app to notify people that they were exposed?
  - What information do you think the app collects from you?
    - What do you think about the data collection?
    - Where is the data being stored?
- How did you learn this information you shared with me about how the CoronAlert app works? (Through the media, through using the app, etc.?)?
- if not mentioned - what do you think the test code is used for, in the process?

**Other CoronAlert-related questions**

- Thinking back to when you first installed the app, can you walk me through your decision about whether or not to install it?
- After installing the app, did you do anything different, or act differently, in the context of the virus ?
- Would you say that installing the app had changed your risk perceptions?
- How did you find out about the app?
- Did you have any concerens regarding using the app? What were they?
  - Do you still have these concerns now?
  - If yes: what made you decide to continue to use the app despite these concerns?
- Have you experienced any challenges with CoronAlert? What were they?
- Are there any parts of the app which you do not like? What are they?
- Have you experienced or had the feeling that your phone's behaviour had changed since installing the app?
- Did you have any privacy concerns regarding using the app?
- What do you think about the app's role in slowing down the spread of the virus? (Do you think it's effective?)
  - What do you think others are thinking about it?
  - Has your perception changed at all over the period of the pandemic? Why/why not?
  - Has your perception changed at all since you have installed the CoronAlert app?

**Environmental Corona-related perceptions**

- What do think about the way the authorities are handling the pandemic? (both higher level of the government actions and also local, from your experience, if you had, with health authorities and local rules)

## C CODEBOOK

Table 2. Codebook

| High-level Code | Subcodes | Illustrative Quotations |
|---|---|---|
| **Bluetooth** | | "Well, because I have a smartwatch and so it stays connected. And well, the corona alert app also works on Bluetooth." P7 |
| **Installation** | Privacy concerns | "I was a bit concerned about the privacy reasons. But I was convinced that this is technically sound, and that it's all safe locally and that it should be fine." P8 |
| | Concerns other than privacy | "When I was in France, I heard something about the app; was mostly negative because signal wasn't very good." P10 |
| | Finding about the app | "I think it was on the news that the app was launched." P2 |
| | Decision to install | "So I said, okay, when it comes to Belgium, I want to install it because I want to know if I have like some risk, and also I want to alert other people." P13 |
| **Use** | Changed way of use | "Yes. Because in the first month, it was mostly to see if I had a risk. And now it's mostly to see how things are going in general in Belgium." P13 |
| | Changed frequency of use | "Like once the regulations were a bit less strict and we could go out with more people, then I also started using it more often." P2 |
| | Not actively using the app | "It's just on. I figure if I come in contact with someone, I will get a notification or something." P7 |
| | When bored | "I check it quite often, mostly when I'm bored." P5 |
| | Frequency of looking at the app | "Once every two days, let's say." P11 |
| | Tracking red screen | "But yeah, I just look at it every other day to see if my screen is not red." P1 |
| | Tracking green exposures | "I go to see how many contacts I have. How many low risk contacts." P5 |
| | Source of extra information | "You basically using the app as extra information source in case of an exposure." P6 |
| | Used for testing purposes | "Yes. For the purposes of if I get a test, and I'm tracking my test. Those are the two main purposes." P10 |
| | Statistics | "And the percentage if it has gone up or down. .... So I usually just check the numbers." P3 |
| | Assumption of age differences | "I suspect it is more maybe younger people who are using the app more heavily, or those who are maybe a bit more comfortable with the technology." P9 |
| | Uninstalled | "When I went to my home country .... And then I installed it when I came back a bit later because then I was in isolation for 10 days." P11 |
| **Notifications-related use** | Red screen | "And the first time..., I got the message from red screen." P12 |

*Continued on next page*

Table 2 – *Continued from previous page*

| High-level Code | Subcodes | Illustrative Quotations |
|---|---|---|
| **Notifications-related use** | Green screen | "I guess it [green screen] makes you slightly more anxious. But because I was not presenting any symptoms I was worried." P9 |
| | Providing the code | "The information was available on the Belgium authority's website. So I trusted it and then I said, okay, no problem [I'll provide the code]." P4 |
| | Getting tested | "Yes, when I entered in Belgium." P4 |
| | Test result | "But to me if I'm honest, I personally contact those people [with whom I was in contact with]. And not only anonymous via the app." P12 |
| **App's effect** | Risk Perception | "It makes me feel the risk is higher than I thought. But as long as they are green, I'm not too worried." P8 |
| | Behavior | "No, it didn't. As I say, maybe I felt a little safer. But my behaviour didn't change." P6 |
| **Attitudes** | Challenges / Suggestions | "It's not that I don't like it. But I wish it will be possible to see a graphics. Visually it represents better where we are right now." P3 |
| | Applause | "I think it's very easy to use; you see everything just by opening it. It works the way I would expect it to." P2 |
| **Effectiveness/ Necessity** | Effective | "It might have helped with the consciousness about it. .... It's one of the tools that the government can use to enter common sense and change behaviour, but it's not the main tool, I guess." P12 |
| | Not effective | "I think it's effective if lots of people use it, but I don't really think. Well, maybe now there are more people. But I don't think there are enough people who are using it yet to make it really effective." P1 |
| | Not sure | "I don't really know how it would affect the spread of the virus. I think it does a very good job at informing people. But I don't think people are going to be much difference." P10 |
| | Why not to install / not so necessary | "So if I should come in contact with someone who has COVID, I believe that I will be informed immediately. And so the app is almost an afterthought." P6 |
| | Depends on population | "And I think the people you are around if they don't have it, then it also doesn't work. So it really depends on the people you are connecting with and getting in contact with." P2 |
| **Environmental effects** | Government | "I think they should mention it more. In the beginning, they talked about the app being part of the solution to this pandemic." P8 |
| | Population | "Now, it looks like everyone is against each other. Like, we're not one whole group fighting against a pandemic anymore." P5 |

*Continued on next page*

Table 2 – *Continued from previous page*

| High-level Code | Subcodes | Illustrative Quotations |
|---|---|---|
| **Mental model** | Anonymity | "And once the person has been confirmed whether a positive or negative test, then it transfers this information back to all the contacts that were made without disclosing which contact in particular was positive or negative, so kind of preserving my anonymity." P11 |
| | App's requirement | "But I guess that when you do a test, they give you a code. And so you can like enter the code into the app... And that's how the app knows." P13 |
| | Test code – perceptions | "So the test code is linked to the app. When the test center has the results I think they present it to a database and the database might be linked to the app, gives information by the test code to your app." P10 |
| | Knowledge source | "I just thought about it, because that's how iOS technologies work nowadays." P4 |
| | Data storage | [where do you think the collected data is being stored] "That's a good question. In the cloud or something." P7 |
| | Data collection | [What information do you think the app collects from you?] "My location. I think that's about it." P3 |