The Dutch CoronaMelder: Do users see added value?

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Abstract

Background: Adoption and evaluation of ICT-based contact tracing tools may expand the reach and efficacy of traditional contact tracing methods in fighting COVID-19. The Dutch Ministry of Health, Welfare and Sports (HWS) initiated and developed a COVID-19 contact tracing app: CoronaMelder. This app is based on Google/Apple exposure notification approach and aims to combat the spread of the COVID-19 virus among citizens, by notifying citizens who were at increased risk of infection because they were close by someone who was later tested positive for COVID-19. The app should support the traditional contact tracing by quicker tracing and reaching more people than regular contact tracing procedures.

Objective: The main goal of this study is to investigate whether the CoronaMelder is able to support traditional contact tracing of Public Health Authorities (PHAs). To achieve this, usability tests were conducted aimed at answering the following question: Is the CoronaMelder user-friendly, understandable, reliable and credible, and inclusive?

Methods: Participants (n=44) with different backgrounds were recruited: young people with a lower or higher level of education, young people with an intellectual disability, migrants, adults (40-64 years) and elderly (65> years) via convenience sampling in the CoronaMelder test region Twente, The Netherlands. The app was evaluated with scenario-based think-aloud usability tests with additional interviews. Findings were recorded via voice recordings, observation notes, the Dutch User Experience Questionnaire (UEQ-Dutch) and some participants wore eye trackers to measure gaze behavior.

Results: Our results show that the app is easy to use. Yet, problems occurred with understandability and accessibility. Elderly and young people with a lower level of education do not understand why or when they receive notifications, or why they must share the key, and what happens after sharing. Especially young people with a lower level of education did not trust and understand the Bluetooth signals, timing and follow-up activities after risk exposure notification and elderly had difficulties in multitasking (contact with PHAs simultaneously with sharing key in app). PHAs appeared unprepared to be supported by the app in traditional contact tracing, because their telephone conversation protocol lacks guidance, explanation, and empathy.

Conclusions: The study indicated that the app is easy to use, but participants have misconceptions about its functioning. The perceived lack of clarity led to misconceptions of the app, mostly regarding its usefulness or privacy-preserving mechanisms. Tailored and target group specified communication, in forms of public campaigns or social media, is necessary to provide correct information about the app to Dutch citizens. Additionally, the app should be presented as part of the package of national corona measures, instead of just as a stand-alone app provided to the public. To succeed, PHA workers should be trained to effectively and empathically instruct users to warn others by using the CoronaMelder app.

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Original Paper

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Keywords: Usability testing; User Evaluation; User Experience; Contact tracing apps; CoronaMelder; COVID-19

Introduction

The coronavirus disease (COVID-19 [1]) was first detected in the end of 2019 in Wuhan, China [2]. Since then, the virus has rapidly spread across China and to 146 other countries around the world [3]. On March 11 2020, the World Health Organization officially declared the coronavirus outbreak a pandemic [4]. Consequently, countries all over the world were urged to implement strict interventions in order to limit viral spread and to prevent healthcare systems from overload [4]. Key essentials of these interventions focus on reducing the risk of transmission of COVID-19 and consist of a package of instruments which are implemented worldwide and based on earlier pandemics. They include behavioral measures (social distancing, handwashing, personal protective equipment); adequate resources (personnel and materials for massive-scale testing, contact tracing and supported isolation); monitoring symptoms (contact tracing of possible contaminated people); and the use of digital tools [5, 6].

In traditional contact tracing approaches, Public Health Authorities (PHAs) follow protocols, which aim '*to interrupt transmission chains by ensuring that persons who have been in contact with an infected individual are notified that they are at increased risk of infection and how to take action to prevent passing the infection to others'* [5]. This is important, because although the coronavirus incubation period has a range between 1 and 14 days [7], and an infected individual can already transmit the virus up to 48 hours before the onset of symptoms [8]. Besides this, some infected individuals will not develop symptoms but are still infectious [9]. According to the contact tracing protocol, the PHAs 1) contact positively tested citizens; 2) consult them with the measures; 3) identify together with them how or by whom they were contaminated; 4) list and contact all citizens with whom they have been in contact with; and 5) arrange that citizens' contacts can be tested [10]. Despite being successful, these traditional contact tracing by public health staff, is also labor intensive, slow, and error-prone because citizens do not remember all the contacts they have had [11, 12]. Therefore, the European Centre for Disease Prevention and Control recommended the usage of

digital tools, such as mobile tracing apps, to augment and optimize traditional contact tracing [5].

Contact tracing apps could potentially provide several benefits; 1) they do not rely on the memory of the user (reminding users with whom they have had contact); 2) the app allows contacts unknown to the user to be notified; 3) the app can speed up and augment the tracing process; and 4) the app may facilitate further follow-up of contacts by PHA [5, 9, 13]. However, there are also some limitations with using these apps: not everyone has a smartphone, or is able to carry their phone with them at all times, older smartphones or operating systems may not support the apps (e.g. newly developed apps can only operate on smartphones with operating system iOS 13.5 or Android version 6, or later), the tracing technology inherently produces false positives and false negatives, and there are privacy concerns [5]. Furthermore, not all citizens will be capable or willing to use these apps, for example, elderly or vulnerable populations [9]. Therefore, these apps may complement but can never replace regular contact tracing systems coordinated by PHA [9].

The Dutch Ministry of Health, Welfare and Sports (HWS) created conditions for the implementation of such an app. These conditions are listed in a Plan of Requirements [14] and include that:

- The app should be **anonymous and voluntary** to use (not possible to identify a person)
- The app should be **developed open-source** (co-design in an open Figma design platform; everyone can be involved)
- The app **notifies users when they have had an increased risk** (users receive a notification when their phone was in contact with the phone from a contaminated person; in that case, it should be possible that the user asks for a corona test, even without symptoms)
- The app is in line with **Guidelines for Infection Control [15]** of the National Institute for Public Health and Environment
- The app **operates in addition to manual contact tracing** of PHAs (citizens do not receive help through the app that they would not receive without the app) and is integrated where necessary, to allow a positive test result to lead to an anonymous contact report
- The app **is inclusive** (the accessibility is aimed at the largest possible relevant target group, by explicit attention to language, literacy, and (digital) limitations)
- The app should **aim to prevent reporting false positive reports** (and avoid that no notification of risk is sent when it should)
- The app should **involve international cooperation**. The app should be available on all phones operating on iOS and Android systems, connections between app users are made via Bluetooth, protection of privacy should be guaranteed (the app should be in line with common security standards, Web Content Accessibility guidelines and Data Privacy Impact Assessment should be performed), and calculation of risks (distance, duration and date of exposure) is performed by Google/Apple Exposure Notification framework [16].

Contact tracing apps from other countries were examined by experts [17] to evaluate if these apps could also be implemented in the Netherlands. The apps included in this “appathon” showed differences in levels of intrusiveness. In Asian countries, usage of contact tracing apps is mandatory, individuals are traceable, and there are penalties for those who go outside without permission [18]. Less intrusive apps operate using Bluetooth, and users are not individually traceable [18]. Besides

the internationally available apps, concepts of the Dutch apps were also considered by the HWS. However, none of the evaluated apps met the above-mentioned criteria. Therefore, the HWS decided to develop a COVID-19 contact tracing app using the Google and Apple notification Framework and that would be interoperable (to facilitate cross border use of the app): the CoronaMelder. A development team, supported by an advisory committee and four taskforces, was assigned to develop and test CoronaMelder. In the design of the app, a privacy-by-design approach was followed, to minimize privacy invasion. During the development of the CoronaMelder, the app was tested with a variety of (end)users in several ways.

- A field test was conducted by the military services (Vught, 8 June), to test the Bluetooth exposure logging mechanism (signal strength and distance; the influence of walls, pockets or telephones on the Bluetooth connection) to determine the reliability of receiving notifications; and to determine optimal settings of parameters [19].
- Think-aloud usability tests were performed (region Twente, 29 June – 3 July) with users having a different SES-background, education level and age, to evaluate whether the app is user-friendly, easy to use, understandable, accessible, and inclusive; and whether it supports manual contact tracing of PHAs.
- Practical tests were conducted in five PHA regions to test how the CoronaMelder operates as an addition to manual contact tracing of PHA (17 August – 15 September).
- Digital security of the app was tested with Web Content Accessibility Guidelines via penetration tests, in which the app was tested on inclusivity and accessibility for target groups with visual impairments (6 July); risks to privacy are mapped via Data Privacy Impact Assessment (7 July).
- Ethical tests with experts and citizens were conducted to identify an ethical framework for the design of the CoronaMelder (29 June cq. 14 August) [20].

Findings of these tests led to continuous evaluation of the development and implementation of the CoronaMelder [20].

This paper focuses on the added value of the CoronaMelder app to support contact tracing. Think-aloud usability tests were conducted during the test period 29 June – 3 July, in the selected test region Twente. PHA region Twente was chosen as the test region for the current study, because of their willingness to participate, their available expertise, and the corona-proof test infrastructure of the University of Twente. The usability tests aimed to evaluate the user-friendliness, understandability, reliability and credibility, inclusiveness, and user experience of the CoronaMelder. These criteria were chosen because the CoronaMelder could only support traditional contact tracing of PHAs if it satisfies these criteria. As the app is to be used by the public, so it needs to be inclusive by being understandable and usable by a large variety of users, with regards to digital literacy, educational background, and ethnicity. Therefore, different target groups were involved in the usability tests. The findings of this study contribute to the improvement of the design of the app and support the HWS in their decision whether to launch the app, or not. This paper aims to answer the following question: *Is the CoronaMelder user-friendly, understandable, reliable and credible, and inclusive?*

Methods

Setting

The study consisted of scenario-followed usability tests with additional interview questions and the Dutch User Experience Questionnaire (UEQ-Dutch) [21]. The usability tests were conducted using a scenario-based think-aloud method [22], captured by researcher observations and voice recordings. The tests took place between 29 June 29 and 3 July 2020. A beta version of the app was tested using test phones with iOS (version 0.1, build 172) and Android (version 0.3.1, build 107). Mock-ups (Figma version 0.7.1) were used for the scenarios which could not be tested in the beta version due to the current stage of development (i.e., the scenario of downloading the app from the App Store). The study was conducted in the DesignLab of the University of Twente and in the mobile lab "Experivan" [23] visiting participants with an intellectual disability at their workspace. The BMS Lab protocol for corona-safe human-related research has been approved by the Executive Board of the University of Twente. Hands and equipment were disinfected before and after the tests and the national measures (RIVM [24]) were followed. The study was approved by the University's Ethical Committee (BCE200953).

Participants

Participants were recruited using convenience sampling in the region of Twente, the Netherlands.
To test whether the app is inclusive, participants from the following target groups have been included:

- Young people (<21 years) with a lower level of education (n=14). Including primary education and prevocational secondary education
- Young people (<21 years) with a higher level of education (n=5). Including senior general secondary education, pre-university senior secondary vocational education, higher vocational education, and university education
- Young people with an intellectual disability (n=4)
- Migrants (n=2)
- Adults (40-64 years) (n=5)
- Elderly (65> years) (n=14)

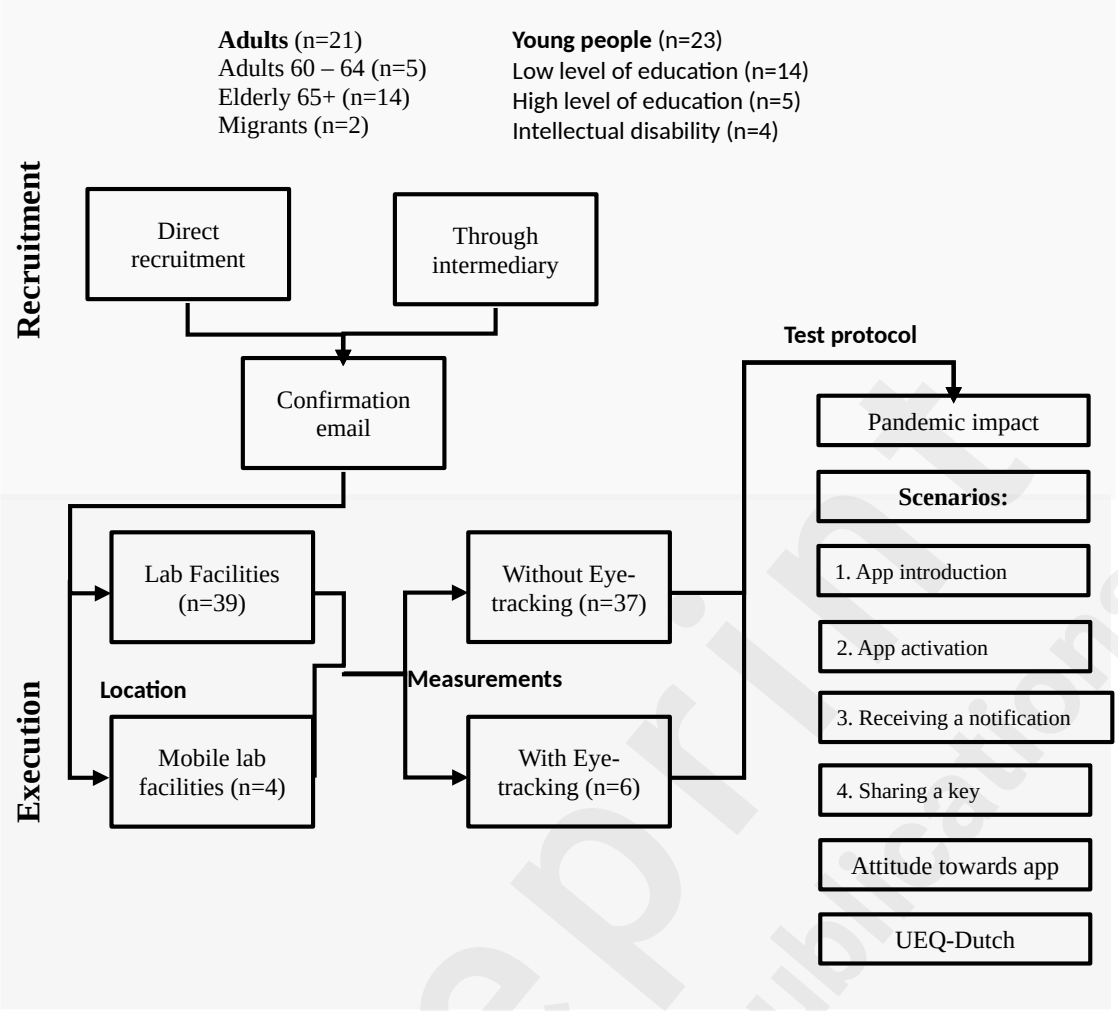


Figure 1. Flowchart of study recruitment and procedure. The Top part visualizes the recruitment methods, through both direct (n=21) and indirect (via intermediaries/representatives, n=23) channels. Included participants were tested in a stationary and mobile lab, with or without additional eye-tracking, following the test protocol depicted on the right.

Procedure

The adults 40-64 years, elderly 65> years and migrants were contacted by telephone by the researchers. In this conversation, an explanation about the nature and purpose of the study was provided, and an appointment was scheduled for the test. Recruitment of the young participants was arranged through an intermediary (e.g., school principal, mentor), and they were also contacted by telephone. After the telephone conversation, all participants (or intermediaries) received confirmation about the appointment by email, which also included additional information regarding participation. Figure 1 provides an overview of the procedure for participants.

The usability tests were conducted individually and in pairs (in case of young people with a lower level of education). Because Research shows that minors respond better while in pairs, identifying a larger number of problems and more detail [25]. Before the test, the nature and purpose of the study were explained again, and permission for participation and audio recordings was given by signing the informed consent. After giving additional consent, 6 participants additionally wore Tobii eye-tracker glasses for gaze analysis. Those results are discussed in [26] and are outside of the scope of this paper.

The test protocol (Appendix 1) started with general questions about the impact of the

pandemic on the participants' lives and about what they had already heard about contact tracing apps for COVID-19. Thereafter, each participant actioned 4 scenarios on the app, which represented actual use of the app (1 hour test) while simultaneously thinking aloud. Before the usability test started, participants could choose between an iOS and Android test smartphone, based on their own preference. The four scenarios were as follows:

1) **Introduction to the app**: In this scenario, the app was shown in the App Store and additional information about the app could be read. Researchers focused on whether participants understood how to download the app and where they could find additional information, and, whether they read the information.
2) **Onboarding and activation of the app**: In this scenario, the app's operation was explained through onboarding steps, in which participants learned about the content of the app and confirmed the right settings to use the app (allow the app to use Bluetooth and to send notifications). After completing the onboarding, the app was activated, and the participants had the opportunity to explore the app independently. Researchers focused on whether the explanation of the app's function was clear, how participants acted and whether they understood the permissions they gave.
3) **Receive notification**: In this scenario, the participants received a notification from the app about their increased risk of contamination, because they have been in close contact with an individual who had tested positive for the coronavirus. Researchers focused on whether participants understood what a notification entailed, whether it was clear to them why they received a notification and on what the increased risk was based. In addition, it was examined whether it was clear to the participants what actions they should take after receiving a notification.
4) **Sharing keys (telephone conversation with PHA)**: In this scenario, participants were asked to imagine they had been tested for coronavirus recently. During the scenario, the participants received a phone call from the PHA, in which they heard they tested positive for coronavirus. The PHA worker followed the Dutch GGD telephone script (Appendix 2), in which the participant was asked about their symptoms, and received help with sharing the key. First, the participant had to mention the key to the PHA worker on the telephone. Second, the participant had to click on the button to share the key with other app users (to warn the people with whom they were in contact with).

After completing the scenarios, closing interview questions were asked about the participants' attitude towards the app and their willingness to use the app. Additionally, a questionnaire was administered. This questionnaire (Appendix 3) included general questions regarding the gender, age, highest completed education, physical limitations in the usage of apps, and self-reported digital skills assessment, combined with the UEQ-Dutch. Within the UEQ-Dutch participants had to assess different characteristics of the app on a 7 point-Likert scale, whether the app is easy to learn, attractive to use, supportive or reliable. Researchers focused on whether the steps to be completed on the app were clear and easy to follow, and whether participants understood the utility and consequences of sharing their key. Differences between target groups were explored to investigate whether the app is inclusive. Furthermore, it was examined whether the conversation with the PHA matched with the steps that must be completed in the app.

Data analysis

The recordings of the usability tests were pseudonymized (BB) and stored on a data server at the University of Twente and were only accessible to the researchers involved. This storage and associated processes were certified according to ISO/IEC 27001 and NEN 7510 standards. Recordings of three participants (1 young person with a higher level of education and 2 young persons with an intellectual disability) were not stored correctly, these participants were therefore excluded from this study. Recordings were transcribed verbatim (MS, LB, JG) and all transcripts were analyzed (BB and MS) to identify fragments concerning user-friendliness, understandability, reliability and credibility and inclusiveness. Relevant fragments were labelled with the main codes ‘User-friendliness’, ‘Understandability’, ‘Reliability and Credibility’, and ‘Inclusiveness’. in Microsoft data. After, the fragments within the main codes were analyzed axially to link fragments to each other and create new sub-codes within each main code. Two researchers (BB and MS) coded six transcripts together to determine coding agreements. BB and MS coded each half of the other transcripts while considering the coding agreements. The coding scheme was revised several times by both researchers and fragments were re-read and recoded.

Results

This chapter discusses the participant demographics, user-friendliness, understandability, reliability & credibility, and inclusiveness results.

1. Participants

In total, data of 44 participants were included in this study. Three-quarters of the participants were male (*n=31*) with a mean age of 44 years old. 26 participants reported to have completed a higher level of education. The majority indicated they do not have physical limitations in the use of apps in general. Almost everyone considered their own digital skills to be at least ‘not handy, not clumsy’ to ‘very handy’. All characteristics in detail are listed in Table 1.

Table 1. Demographic data of participants (n=44)

		Frequency	%
Average age in years (min-max)		44 (13-79)	
Gender			
	Male	31	70.5%
	Female	13	29.5%
Highest completed education level			
	No or primary education	12	27.3%
	Preparatory Secondary Vocational Education (practical)	3	6.8%
	Preparatory Secondary Vocational Education (theoretical)	3	6.8%
	Secondary Vocational Education	0	-
	General Secondary Education/Secondary University Education	6	13.6%
	Propaedeutic (Higher Professional Education or Scientific Education)	4	9.1%
	Bachelor's degree (Higher Professional Education or Scientific Education)	4	9.1%
	Master's or doctoral degree	12	27.3%
Physical limitations in the use of apps in general			
	I have trouble reading	2	4.5%
	I am dyslectic	1	2.3%
	I am visually impaired	0	-
	I have a motor disability	0	-
	I am hard of hearing	1	2.3%
	Limited digital skills	2	4.,5%
	Otherwise, namely…	1	2.3%
	No	36	81.8%
	Did not state	1	2.3%
Self-reported digital skills assessment			
	Very handy	9	20.5%
	Handy	22	50.0%
	Not handy, not clumsy	12	27.3%
	Clumsy	1	2.3%
	Very clumsy	9	-
	I do not know, no opinion	0	-

The following sections will focus on the research question: *Is the CoronaMelder user-friendly, understandable, reliable & credible, and inclusive?* Table 2 presents an overview of the number of participants per target group, who stated a positive or negative argument about the CoronaMelder, or indicated to understand the topic, or not. The majority of the participants is positive about the user-friendliness, reliability, and credibility. About the understandability of the working mechanism of the CoronaMelder, participants from all target groups indicated more negative comments than positive ones.

Table 2. Number of participants who stated a positive or negative comment about the CoronaMelder, per topic (user-friendliness, understandability, reliability & credibility, and inclusiveness). In the case of the understandability of the notification and sharing the key, the table shows how many participants understood the working of the CoronaMelder app. See appendix 4 for an overview of the number of positive and negative comments per topic, per target group.

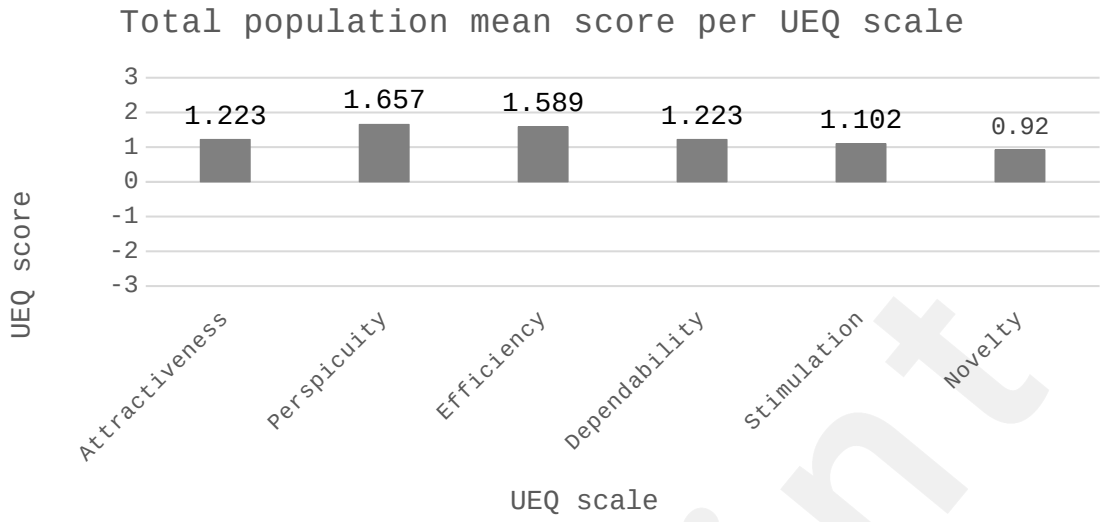
		Positive	Negative
		Do understand	Do not understand
User-friendliness	**Lay-out**	23 (53%)	8 (18%)
	Navigation	33 (75%)	9 (20%)
Understandability	**Language**	7 (16%)	10 (23%)
	Receiving a notification	15 (34%)	21 (48%)
	Sharing the key	15 (34%)	19 (43%)
Reliability and credibility		19 (43%)	6 (14%)
Inclusiveness		5 (11%)	9 (20%)

2. User-friendliness

User-friendliness was assessed with both the User Experience Questionnaire (UEQ) and in the interview. In Graph 1, the outcomes of the UEQ-Dutch for the entire population are displayed for each of the six assessed scales. The scales include Attractiveness (an overall impression of how users like or dislike the app), Perspicuity (how easy it is for participants to get familiar with the app), Efficiency (the ability of users to use the app as intended), Dependability (does the user feel in control of the interaction with the app), Stimulation (is the app exciting and motivating to use) and Novelty (does the app catch the interest of the user).

Participants assessed the CoronaMelder app between 0.9 and 1.7 for all scales, what represents a positive evaluation (values > 0,8) [27]. On Perspicuity and Efficiency, the app was assessed relatively high, meaning that participants indicated the CoronaMelder as easy to get familiar with and that they are able to use the app as intended. The CoronaMelder scored relatively low on Novelty, meaning that the CoronaMelder does only slightly catch the interest of the user.

Graph 1. Boxplot with a mean score per UEQ scale for the total population, scoring from -3 (horribly bad) to +3 (extremely good). The error bars show confidence intervals.



2.1 Lay-out

The interviews showed most of the participants appreciated the style of the app. The use of pictures within the app was appreciated, particularly by young people with an intellectual disability, who indicated having difficulties reading long texts. Representation and inclusiveness were achieved by displaying images of people from different cultures (Figure 2 and 3). The examples of being exposed, or not, to an increased risk (Figure 2 and 3), were praised because these helped the participants understand better when they were exposed. *"['Where do you pay attention to base on what you have read so far, what is important for you?'] 'That it is explained in a simple way and that not too many words are getting used' ['And do you think that this is the case here?'] 'Yes'" (Participant 38, young people with an intellectual disability)*

Figure 2. Screenshot shown during the onboarding, with an example of when users are not exposed to an increased risk. Translated as: “Did someone cycle past you? Then you will not receive a notification later”.

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Figure 3. Screenshot shown during the onboarding, with an example of when users are exposed to an increased risk. Translated as: “Were you too close to someone on the train? Then you can receive a notification later”.

As a negative aspect, participants reported not reading long texts (e.g., Appendix 5) or only to quickly scan the text by reading the subheadings and words in bold to understand the most important

information. *"Well, I only read the bold letters. I always want to be able to download an app quickly, so I am not going to read everything. The smaller, non-bold letters are then less important, I guess, so actually I skipped those."* (Participant 2, Adults).

A few participants suggested videos in which the information within the app is explained in more detail would be useful because not everyone likes to read, or might not be able to read well. Also, using visualizations was recommended: young people with a lower level of education and young people with an intellectual disability were not able to understand how the app works, by only reading the informational texts within the app. *"It might have been useful to design a human with a mobile phone, standing with a group of people, of whom one appeared to be infected, and they all use the app. If there are 5 people and 1 has the virus, then if you make it visual how the app contacts other apps; you can explain what Bluetooth does. Because I don't know if everyone knows what Bluetooth is."* (Participant 20, Adults)

2.2 Navigation

Most comments on navigation were positive, for example, participants indicated the flow of information as logical. Although, multiple issues with navigation were identified. First, from the Play Store (Figure 4), it was unclear that an additional information page with further explanation of the app could be opened. Therefore, it was not read by every participant. In particular, older participants did not know it was possible to consult additional information, although they reported that they want to read extra information.

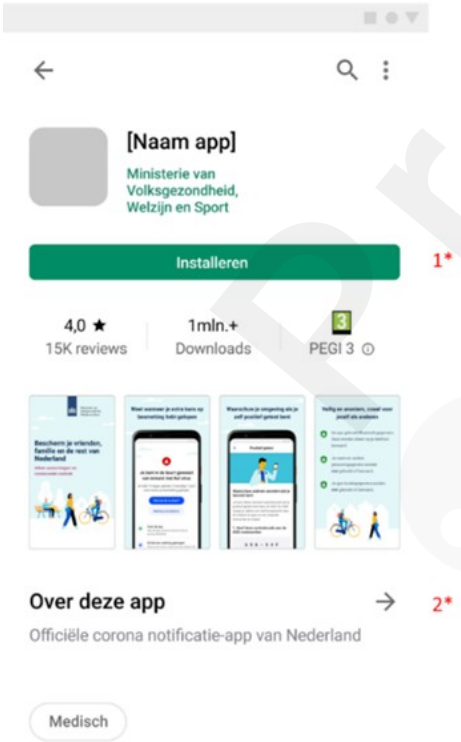

Figure 4. the app within the Appstore. The app can be installed when clicking on the button labelled with 1*. Additional information can be found under 2*.

Second, within the app, some buttons (Figure 5; 3* and 6; 1*) were only visible after scrolling the screen below, which was not clear for few participants who therefore could not find the button. *"I*

didn't know there was another fourth button […] Sometimes you think that what is visible here, is everything. Then I will not go scrolling automatically, but that can also be me." (Participant 27, Adults) The text informs users that they warn others anonymously (figure 5; 1*). Users must mention the key (Figure 5; 2*) to a PHA worker to validate their positive test. Afterwards, they must click on the 'share key' button (Figure 5;3*) to warn other app users who they have been in contact with in the last 14 days. Figure B shows the screen that opens after users click on the notification they received after being exposed to an increased risk. The screen provides information to users about the date when they were in contact with the contaminated person, provides the symptoms of COVID-19 and recommends users to get tested. The button below (Figure 5; 2*) allows users to directly call the PHA to request a test.

Third, the app did not provide clear expectations for the participants what to do after the activation of the app. After activation, the home screen (Figure 7) displays, which says the app is activated and ready for use. Younger participants automatically closed the app, older participants got disorientated and reported to be unsure about what to do next. "*You could also put that in the text 'the app is active and if you are sufficiently informed you don't have to do anything', because people will ask 'what now?'*" (Participant 8, Adults)

Figure 5. Screenshot of 'Positive tested' page. The text informs users that they warn others anounymously[1*]. Users must mention the

key[2*] to a PHA worker to validate their positive test. Afterwards, they must click on the ‘share key’ button[3*] to warn other app users they have been in contact with in the last 14 days.

Figure 6. Screenshot of ‘Positive tested’ page. The text informs the user what to do after receiving a notification of being exposed to an increased risk. When users click on the button below 1*, a corona test can be quested in a telephone call.

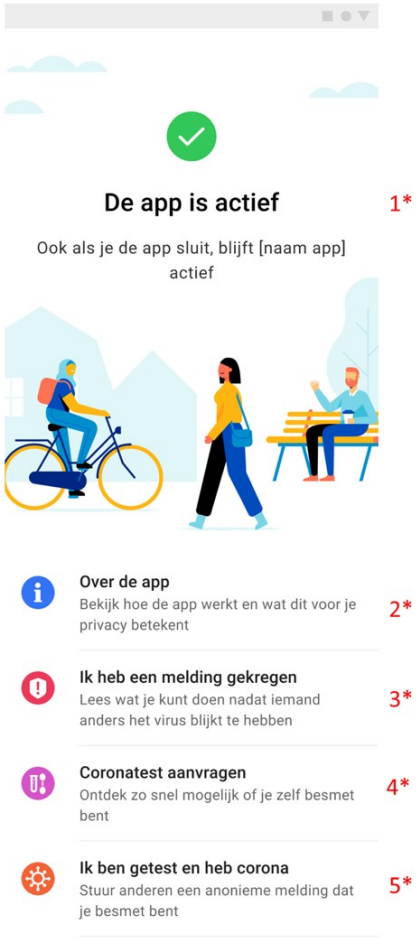

Figure 7. The home screen of the app, which displays after the user has finished the onboarding and activation of the app. At the top[1*] the app explains to be activated for use. Below, several information pages are displayed, such as: [2*]Information about how the app works, [3*]Information about what to do if you receive a notification (Figure 6), [4*]Requesting a COVID-19 test, and [5*]Positively tested (Figure 5).

Positive remarks on navigation were that the steps to onboard and activate the app were performed easily and the sequence flow of providing information about the app within these onboarding screens (Figure 8-16) was reported as logical. Majority of both the older as well as the younger participants indicated that they normally would click quickly through the screens, and only read the information properly as they participated in this study. The young participants gave permission to receiving notifications and using Bluetooth without even thinking, while older participants thought carefully about their choice for permission. *"Most of it is very logical. I read the texts now properly, but usually I would probably click and skip faster through it."* (Participant 4, Elderly)

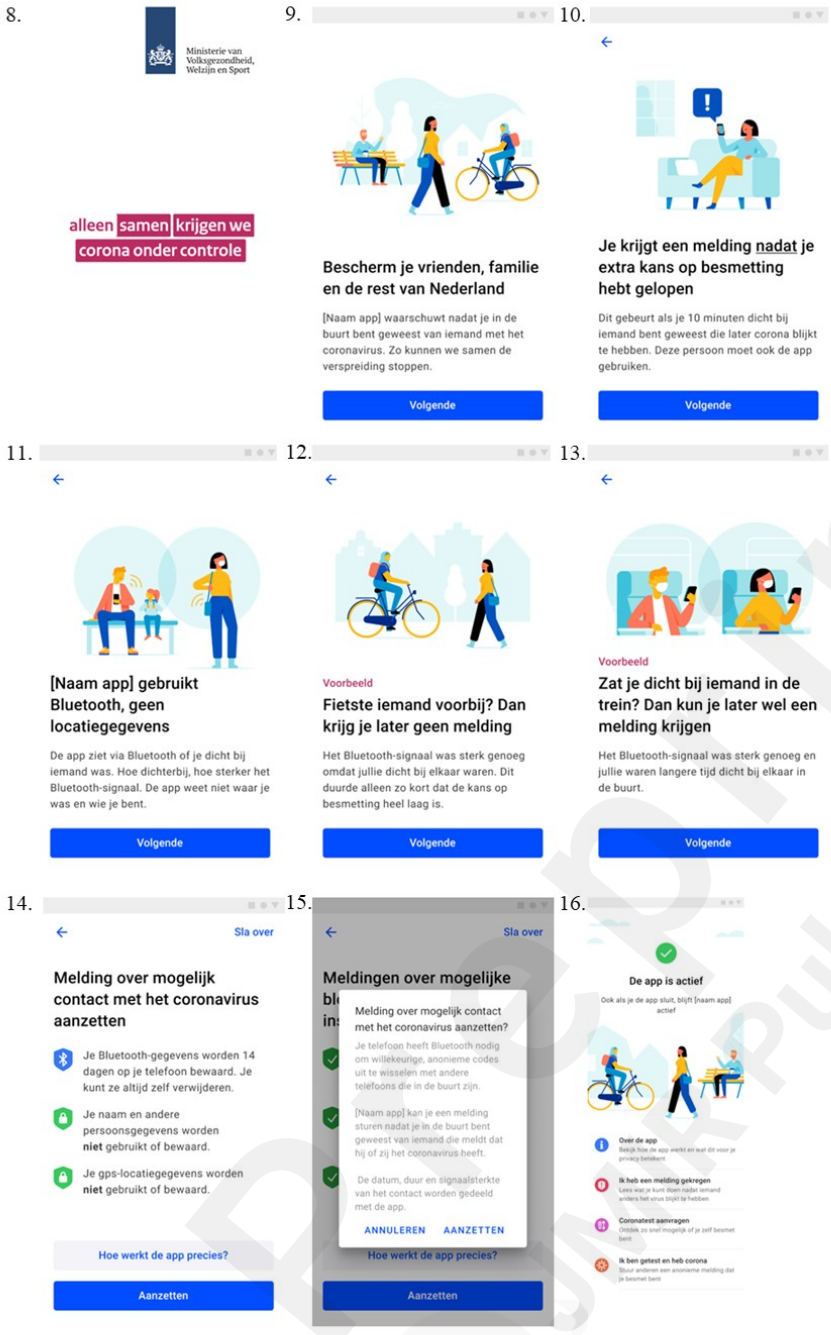

Figure 8-16. Screenshots of onboarding and activation of the app. The screenshots include the following information: Figure 8. Start screen with Dutch COVID-19 combat slogan, Figure 9. How the app operates, Figure 10. When you will receive a notification, Figure 11. explanation about how the app uses Bluetooth and no additional data, Figure 12. Example of when you will not receive a notification (Figure 2), Figure 13. Example of when you will receive a notification (Figure 3), Figure 14. Giving permission to allow the app to use Bluetooth, Figure 15. Giving permission to receive notifications of the app, and Figure 16. The app's home screen which occurs after the onboarding steps are performed and the app is activated and ready for use.

3 Understandability

Participants from all target groups stated more negative comments regarding the understandability of several topics, than positive ones. Understandability problems occurred due to inconsistency in terms used, and not reading information about how the app works. Most problems concern receiving a notification from the app and sharing the key when positive tested to support contact tracing. The

app is inconsistent in using terms what refer to the coronavirus (e.g., “coronavirus”, “COVID-19” and “corona”) and to the key that should be shared after being tested positively (e.g., “ID”, “code”, “control code”). Furthermore, a clear definition or explanation is lacking within the app about what it means to be exposed (“exposure”) or being at “increased risk” of a COVID-19 infection. The texts also include technical vocabulary, such as “ID”, “Share”, “Enable” and “Upload”. Particularly, older participants did not know what those words meant, and they were confused by them. *“Now suddenly some English words are used. Well, that is a problem for some people. You should not do that. Or you should provide both languages. But now you have people who stick around here […] this can confuse people.”* (Participant 4, Elderly)

3.1 Understandability of receiving notifications when being exposed to an increased risk

The app sends a notification message to the phone which explains that the user has been at increased risk because they were close to another app-user who was later tested positive, for more than 10 minutes, on a certain date. Opening the notification brings the user to an information page in the app which explains what the user should do.

3.1.1. Being at risk, when and how a notification will be received

The test showed that the majority, but in particular young participants with a lower level of education, do not understand under what circumstances they will receive which notification; for example, they thought they would receive an alarm immediately after exposure. “*But I am not quite sure how it exactly works, whether it’s anonymous or when you receive a notification… If I understand correctly, you will receive a notification if you have been with someone for more than 10 minutes, but then you do not know whether the person is infected or not? And when they have been tested, you will receive a notification that they were infected. Can I figure that out based on this? Well, I don’t think so*” (Participant 32, Elderly)

Higher educated youth and adults (including elderly) also reported that the time between exposure and notification (within 14 days) is too long, although they can imagine why that is. A few participants even reported the app as useless when they do not receive a notification immediately after being exposed, because when they receive the notification afterwards, according to them, it is too late to take appropriate action. “*It would be nice if, for example, someone has corona, then if you walk by, your phone will beep at once, like a message will be given […] Because after five days, it is already too late. If someone has the coronavirus and you immediately get a message, then you know, oh I must keep my distance*” (Participant 14, Young people with lower level of education)

All participants, regardless of age and education, did not understand when they have an increased risk for possible contamination. For example, for how long and how close they must be near someone who appeared contaminated later, to receive a notification about being exposed to an increased risk. Participants also appeared not to understand that the app only contacts with other apps, so they will only receive a notification if the contaminated other also uses the app. It is unclear to participants that this exposure is based on Bluetooth connection between different apps, and not on actual being exposed to the contaminated persons themselves. The exposure threshold level raised questions: why 10 minutes? Participants (no difference within target groups) think they can also be contaminated when they are less than 10 minutes close to someone. “*But 10 minutes… isn’t that*

quite long? Suppose he has coronavirus and I stand with him for 2 minutes and then leave… […] 2 minutes is enough anyway." (Participant 15, Young people with a lower level of education)

3.1.2. What to do after receiving a notification?

While young people with both lower and higher level of education indicated that the app explains well what to do after they receive a notification, adults and elderly mentioned that the app does not give clear advice, or even gives contradicting advice. For example, the app advices to stay at home, but also to continue daily life, while being aware of symptoms. "*But what I do want to know – and I miss that in here – is: what should I do now? I would like to know very specifically: what should I do? What options do I have? […] Or even more socially democratic: we recommend the following […] Suppose if you receive a notification, I want to know what now? What should I do? Then I do not need to know about symptoms or about a corona test..."* (Participant 12, Adults). Participants emphasized the app should clarify how the app notifies users, and what users are expected to do after receiving this notification. A few participants reported that it is not interesting to provide information about symptoms of the coronavirus and the possibility of applying for a test, but they prefer to read pieces of advice of what they should do at that moment. *"If you get a notification, 1) I want to know how I get this notification, 2) suppose, I have received a notification, what now? What am I supposed to do? I don't need then to know about symptoms or about a corona test*". (Participant 12, Adults)

3.2 Understandability of sharing a key when positively tested

Various understandability issues were identified in the scenario of a positive test, as well as some positive remarks. The issues revolved around: not understanding what the key is, where to find it, when to share it, and how to share it. For example, some participants mentioned they did not know what the key (Figure 5; 2*) involved, or what was expected of them to do. "*Well, I see now that it [the app] works through a key and I haven't read about that anywhere yet. So, I don't know what that key involves."* (Participant 12, Adults) Participants also appeared not to know that the PHA will contact the participant by telephone to share the key: "*Now they say, 'then the PHA worker will ask you in the telephone conversation to share the key from the app and then upload the keys of the telephones from whom you've been in contact with.' What are they talking about? Which key? I don't know what key they are talking about*." (Participant 12, Adults) A few young participants with a lower level of education or an intellectual disability did not understand how the app knows that you have been tested positive. "*But how does the app know you have corona? Do you have to type that in the app?"* (Participant 15, Young people with a lower level of education)

Participants expressed different opinions regarding the text about sharing the key (Figure 5; 2*). Young people with a lower level of education appeared to easily share the key, and they did not want information about what was expected from them. A few adults mentioned that the symptoms of the coronavirus and the implemented measurements are repeated too often within the app. The texts were considered as too long, and it was reported that an overload of information should be prevented. Adults expressed their indignation about why the app asked if you want to share your key or not. They mentioned that if people are not willing to share the key, they should not have downloaded the app. "*If I have the app, wouldn't that obligate me to share the key? I think you should share the key,*

that this choice option does not have to be in there. Otherwise, I would not have to install the app. We try to help get this virus under control, together. Together, therefore, means that you must share this information with others. So, I think that this choice to share or not is ridiculous." (Participant 5, Adults)

The steps participants must perform to share the key (Figure 5; 2*) were clear to most of the youth and adults, although some elderly do not understand which process starts after they click on the share your code button. It is unclear for them why they must appoint the key (Figure 5; 2*) to the PHA worker first and whether they must share the key afterwards with other users, when clicking on the button (Figure 5; 3*) Some thought they must send the code to their contacts via other communication channels. "*My question is whether if it says 'share codes', whether this relates to the person with whom I have been in contact […] or whether codes are shared with the PHA, and the PHA then warns people with who I have been in contact with. That's unclear to me*." (Participant 18, Elderly)

Some young participants with a lower level of education reported that when the key is mentioned to the PHA, the app is not anonymous because the PHA knows which person belongs to which key. "*Well, now they suddenly have my number at the PHA? [Yes, that is right, the corona test is not anonymous. But sharing the key is] But if I share my key with them, then it is not completely anonymous, right?"* (Participant 13, Young people with a lower level of education) Besides this, some adults were irritated by the notification (Figure 17), which occurs after sharing the key. They reported that you only use the app if you want to warn others and assessed the extra permission notification for sharing as ridiculous. "*In my opinion, this is a strange choice. […] It was clearly emphasized at the beginning [onboarding] that the app is anonymous. I also think now, since I downloaded the app, I must warn others. That is not a choice, it is a logical consequence of the fact that I installed the app. I specifically downloaded the app because it is anonymized. This is just part of the deal. I have no idea to who I am sending it [the key], I do not know where I was [during the possible contamination], I do not know anything, but I do know that others will receive a signal just like I received a signal. Then I should no longer have the choice of sharing or not sharing*." (Participant 5, Adults)

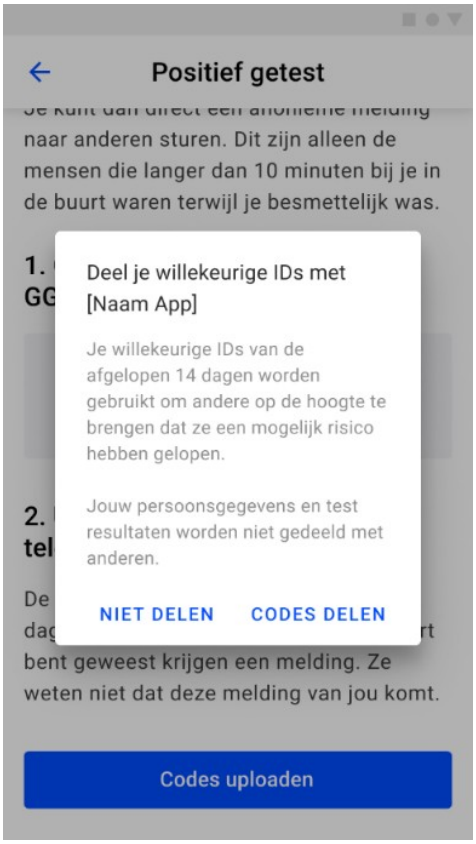

Figure 17. The notification which pop-ups after sharing the key (Figure 5; 2*), which asks the user for permission (to share or not to share) after they clicked on “share the key”.

Participants, except the elderly, indicated the guidance steps of the PHA worker for sharing the key on the app, as clear and easy to follow. "*It was super easy to me. Even a young child can do this independently*.” (Participant 2, Adults) "*This is unclear, how to do that, because there is nothing, the screen says only ‘close’ to me […] Yes, because, what you said to me, I cannot carry out […] No, I only have to close the blue bar […] Maybe I can do that, maybe that will work […] No, I returned to the previous screen…*” (Participant 4, Elderly)

Although, participants expressed that the simulated telephone conversation with PHA lacks guidance assistance, further explanation, and empathy. Participants did not understand what sharing the key involves, for example, with whom they are sharing the key, and what happens after sharing the key with contacts. *“The question is, if it says, ‘sharing the key’, whether it relates to the person with whom I have been in contact, or whether it relates to the PHA, and then the PHA warns the people with whom I have been in contact. That’s unclear to me.”* (Participant 18, Elderly)

However, a telephone conversation was seen as a more personal approach, although young people with a lower level of education level and young people with an intellectual disability do not like to be called and a few indicated not to answer the phone if the PHA calls from an anonymous telephone number. Additionally, too little attention was paid to the emotions that the message of being tested positively can convey to participants. Participants suggested PHA workers should make time for helping participants through the scenario, especially for elder people, and should identify themselves, to confirm reliability. Participants reported that the PHA worker should calmly go through the steps with the app users, and not asked them to perform certain steps without providing explanation. *“I think it is pleasant if someone calls you and goes calmly through the app with you. That they do not just say, well you must do this and that, but that they really explain step by step*

what to do and where I must click on, in the app. That might be useful for older people or people who do not know or understand how the app works. I think that would be useful." (Participant 25, Young people with a higher level of education)

4. Reliability and credibility

The app is assumed as reliable because it is presented as a government app and participants have trust in the Dutch Ministry of Public Health, Welfare and Sports. *"[Participant is reading additional information in the App Store] 'Released by the Ministry of Health, Welfare and Sports'. Well, that seems confidential to me*" (Participant 19, Young people with a higher level of education) The explanation about data storage and the anonymous characteristic (Figure 18 and 19) gains trust and in particular adult participants praised the fact that the app does not require personal data. "*I think it's good that they clearly state what makes the app safe and anonymous, I think that's strong […] Otherwise if these weren't listed it would scare people off*" (Participant 21, Young people with a higher level of education)

Figure 18. Screenshots of Frequently Asked Questions (Figure 7; 2*). Explanation that the app does not track GPS.

Figure 19. Screenshot of Frequently Asked Questions (Figure 7; 2*). Explanation about how the app guarantees anonymity.

Although adults reported the app as trustful, the test showed that particularly young people with a lower level of education do not understand how the app guarantees privacy. Participants (from different target groups) expressed they will be tracked and that others will know their name and address when they appeared contaminated. These misconceptions are not only caused by a lack of explanation or not reading the information, but also because participants mistrust the use of Bluetooth. For example, because some participants think it still will track their location and the app will also connect with people who are not directly close to them, for example, because they are separated by a wall. *"It says that the app knows via Bluetooth whether you were close to someone […] The app does not know where you were and who you are. But that's nonsense, it must be. If you turn on Bluetooth, you immediately see where someone is […] That is through the Apple satellite, same for the Samsung satellite. They can always track your phone; it does not matter if you have turned it [GPS tracking] off. That is why it is nonsense, and they should add that. But well, if that is the case, if I already know that someone will use my location, I will immediately delete the app*". (Participant 15, Young people with a lower level of education)

Other participants are less doubtful regarding the use of Bluetooth and reported that they thought the gaining and storage of data was safe. Additionally, if privacy is guaranteed, multiple participants (mostly higher educated youth and adults) mentioned being willing to use the app. *"[…] Of course, related to privacy, you always check who monitors what data, but that will undoubtedly also be properly secured, and your GPS location data will not be used or stored. That sounds safe, and I assume it is*." (Participant 4, Elderly)

5. Inclusiveness

Differences in inclusiveness were found in age groups. In general, participants from all target groups except the elderly did not have any problems with using the app. Within the elderly, there was a dichotomy between participants who were skilled in using technology, and others who had trouble finding specific information within the app (e.g., opening and closing screens, and combining a telephone conversation with opening and using the app). "*Turn on speaker, that will be interesting. I am going to see if I can do that. Speaker, yes, I did it! I succeeded. Well, to the Corona-app, let me ask, how do I get there? These are things I am not handy with. I must go to the app. It works on my own phone, but now it will not. Close everything… no, I should not do that. Ah, this one. Yes, I'm in the Corona-app now*." (Participant 29, Elderly) They were able to perform the steps to share the key (Figure 4, Number 2) with the guidance of the PHA worker, but they had difficulty in performing these steps simultaneously while having a telephone conversation with their mobile phone. For example, the elderly were not aware of how they could turn on the speaker or close the call screen and open the app simultaneously. However, they indicated to be willing to learn how to use the app. "*Oh that is difficult, then I have to make a phone call and look something up in the app. I do not know how to do that. Normally I can't even answer my phone when I'm doing something else on my phone*." (Participant 1, Elderly)

Also, young people with an intellectual disability appear to lean on the researcher while conducting the test. They were doubting and asked for confirmation each time before clicking on a screen or button. They appear not to know what they are doing, and why they must do it. For example, while sharing the key, they blindly follow the steps which the PHA worker told them to do, without showing to understand what they were doing, and what will happen after.

Regarding the language, differences in appreciation of the use of language are observed, related to education or cultural background of participants. For example, higher educated youth and adults (both 45-65 and 65+) reported the language as clear and easy to understand, and uses appropriate words to express the purpose of the app. "*Of course, not everyone can read properly, that can be a bottleneck. The information should be as simple as possible. I think it is easy to read, but I don't know if that applies to everyone.*" (Participant 11, Adults) Young people with a lower level of education, young people with an intellectual disability and migrants reported that the used words are too difficult to understand and texts are too long. The latter indicated that the app should also provide other languages, such as English or Arabic. "*P1: it has really difficult words… P2: I agree, and difficult words are annoying to read*" (Duo Participants 16.1 and 16.2, Young people with a lower level of education) "*Some words I don't understand so well. It would be easier for me if I could choose another language.*" (Participant 41, Migrants)

Discussion and conclusion

This study aims to answer the research question: *Is the CoronaMelder user-friendly, understandable, reliable and credible, and inclusive?* Based on the findings, we can conclude the CoronaMelder is easy to use. The app was seen by a majority as a good initiative because it warns them about possible contamination, protects them and could avoid a second virus wave. The app was considered as

reliable because it is an initiative from the government (Ministry of Health, Welfare & Sports). After participants read the information in the App Store, they indicated to understand how the app operates, and many participants were curious to get to know the app and have the intentions to download it. In general, several reasons why participants were willing to use the app were indicated, such as protecting themselves and their loved ones, creating sufficient support for the app, helping to get the coronavirus under control, and to ease national measures. However, it appeared that key essentials of the app were not understood; participants do not understand the notification and the sharing of the authorization key via PHA (sharing key), or how the app guarantees privacy.

Doubts and fears were expressed regarding privacy, the usefulness, and consequences of the CoronaMelder. These negative attitudes were caused by, for example, less positive arguments in the media and the number of false positives. Reasons not to use the CoronaMelder were indicated, such as perceiving the app as useless, thinking the coronavirus and corresponding measures are overdone, not wanting to be in quarantine (without confirmed risk) and a limited phone memory or battery capacity. Regarding inclusiveness, it appeared the CoronaMelder is not accessible for various target groups. Young people with a lower level of education or with disabilities have difficulties using the app due to low literacy and language problems, elderly experienced difficulties related to fewer digital skills.

Whether the app will be effective in supporting traditional contact tracing is a concern, because the majority of the participants did not understand how the app operates or why there is a delay between being exposed to an increased risk and receiving a notification. The app provides difficult information and lacks explanations; therefore, users find it unclear what actions the app expects from them. The lack of clarity led to misconceptions about the app regarding operation, privacy and usefulness and therefore affect participants' willingness to use the app. Besides, this also affects the adoption and the potential adherence to maintaining the use of the app. Additionally, the protocol of PHA workers lacks guidance, explanation, and empathy, what indicates that PHAs are unprepared to fully support users on the app with sharing keys during the pandemic, in addition to their other responsibilities.

Comparison with studies on (other) COVID-19 tracing apps

To the best of our knowledge, this is the first independent scientific study of pre-testing the usability of the Dutch CoronaMelder app. Reflecting on studies of other countries' contact tracing apps which operate in comparable conditions, similar findings were reported regarding the attitudes of participants towards these kinds of apps. In a study by Horstmann et al. on the German "Corona-Warn-app", participants indicated that there were no reasons not to use the app, that the benefits would outweigh the risks, and that they believe the app will contribute in slowing down the pandemic [28]. On the other hand, in studies of the German, Swiss and French app, the most mentioned reasons not to use the app were privacy concerns [28-34], doubts of usefulness [28, 33, 35], and the lack of technical equipment [28, 33, 36] (e.g. not all operating systems of smartphones are able to access the apps). In both of the studies on the German Corona-Warn-App [28] and the SwissCovid app (Switzerland) [33], as well as in a longitudinal survey about the Dutch CoronaMelder [37], the privacy concerns appeared associated with a lack of trust in the national government (or public health authorities).

In addition, the StopCovid app (France) showed a low uptake [35, 38] because the app appeared uninteresting and ineffective [35]. The same study also reported that 71% of their participants suggested that better communication strategies would increase the uptake of the app. Our study stated that the mentioned reasons not to use the app were already expressed before contact tracing apps were launched. However, it was reported [28, 39] that these concerns were still raised after implementation of the app, which indicates that public health campaigns which promoted the notification apps have not been able to eliminate these concerns.

Lessons learned and recommendations

Adequate and targeted communication

The tests showed that lack of clarity led to misconceptions of the app, which affects participants' willingness to use the app. Therefore, communication about the app is essential for acceptance [6, 28, 39]. Targeted and tailored group-specified communication should be performed through channels such as public campaigns, animations, social media and ambassadors or influencers [6, 40]. The communication should be tailored to the aim of the app in relation to other national corona measures (e.g. testing, quarantine, social distance) [6] and in collaboration with the PHA and general practitioners. Attention should be brought to:

- How risk exposure is registered by means of authorized keys
- How risk exposure will be defined (GAEN notification system)
- Why users will receive the notification of being at increased risk afterwards
- Why it is important that users have themselves tested immediately in case of possible contamination (when receiving a notification)
- How Bluetooth is working
- What role of PHA is related to contact tracing
- Why codes should be uploaded via the app if the test result is positive

Providing more explanation together with emphasizing the advantages of the app in comparison to regular contact tracing, increases the likelihood that when citizens download the app, they will know what to expect and also what is expected from them [28, 34]. Walrave et al. earlier reported that the intention to adopt a contact tracing app increases if citizens know how to use the app [34]. It is also shown that citizens are more likely to use the app if people within their environment also use the app [37]. Yet, if citizens believe their environment will not use the app, this is shown as a barrier for adoption [37, 41]. In addition, a helpdesk would be relevant, where citizens can ask questions, for example about the purpose of contact tracing and how the CoronaMelder contributes to this, how the app operates abroad, how anonymity is guaranteed, how data is stored, what the role of the PHA will be and who can be approached in case of uncertainty or fear regarding possible risks of contamination.

Embedding in traditional contact tracing of PHA

Our study suggests that it is important PHAs are well prepared to guide the users to share the keys in

case of being positive tested. To embed the CoronaMelder within PHA workers' procedure, it is important to consider the app not as a stand-alone tool, but to see it in the pandemic infrastructure [6, 34, 40]. Therefore, it is crucial to:

- Provide access to tests, regardless of symptoms or complaints, but depending on the contact date with an infected person (considering incubation time)
- Proceed testing quickly (on the correct day, indicated in the notification) and deliver test results within 24 hours
- Clarify the scope of the app compared to other digital resources (Dashboard; Thuisarts.nl…) or apps to be developed (e.g., PHA contact tracing app)
- Arrange international agreements about interoperability with contact tracing apps in other countries
- Facilitate effective and efficient interaction between the PHA and the CoronaMelder
- Evaluate the effects of the CoronaMelder on contact tracing, citizens' behavior, and society

PHAs should coordinate how their healthcare workers can guide citizens during the steps of sharing the key with the app. PHA workers should be trained to properly and empathically explain which steps citizens must perform on the app. After all, PHAs are responsible for both conducting the conversation about the test result, as well as instructing the user on the app. This means that PHA workers should be well educated about the aim and operation of the app and about their task and role in the telephone conversation. Therefore, it is recommended to study how PHA workers can proceed effectively and empathically interact with app users.

Strengths and limitations

The first strength of the current study is its focus on participants with different backgrounds (age, education etc.) to test whether the CoronaMelder is accessible for all citizens in the Netherlands. The second strength is the real-time pre-testing of the key essentials of the CoronaMelder, to enable revisions before the definitive launch. The findings of the study were communicated with the software development team to exchange feedback on adjustments to the app and to revise the app during the test days. During development minor adjustments in the app's design were made, which means that participants tested on the later days may saw some other screens than the participants tested in the first days, although the essentials of the app were the same. Based on the findings of this study, the Ministry of Health, Welfare & Sports decided to launch the app (a GO). However, the definitive launch (10 October) was postponed due to changes in test policy. The premise "test without symptoms" which is an important driver for using the app, was changed due to lack of test capacity.

Future research

To fulfil the requirements of the CoronaMelder [14], the design of the app can be improved. The accessibility and understandability of the app should be tailored to differences in literacy and digital skills. Think-aloud real-world-based scenarios and eye-tracking should be designed to involve end-

users with different literacy levels and digital skills to rea- time test the use of the app.

Evaluation of the CoronaMelder app should focus on the key essentials of the app to support early and better contact tracing. Therefore, data should be collected about the use and adherence regarding follow-up actions after a notification, sharing a key to inform PHA and other users (via the app) and going into isolation in case of being positive tested. The privacy-by-design policy could complicate to get insight into the added value of the CoronaMelder app, because it hinders data collection. A critical view is needed how to find a balance between user-centered-design and privacy-by-design.

Future studies should also focus on how communication campaigns can be best targeted and tailored to reduce uncertainties and misconceptions, and so improve the understanding of digital contact tracing apps and improve adoption and adherence. Overall, an adequate infrastructure (resources, personnel, capacities etc.) and powerful management are needed to implement the CoronaMelder and other digital tools to facilitate and support a better contact tracing to fight a pandemic. The COVID-19 pandemic is a “wicked” problem that requires an interdisciplinary based approach. Future studies of the CoronaMelder app should consider the app not as a stand-alone device but as part of a coherent package of corona measurements to fight the pandemic, considering the impact on users, stakeholders and test and trace procedures.

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Abbreviations

HWS: Ministry of Health, Welfare and Sports

PHAs: Public Health Authorities

Authors' contributions

BB and LGP were responsible for the coordination of the usability tests. SK, BB and LGP were involved in the creation of the scenarios and interview scheme. JK, JG and PS delivered the materials. MS, LB, JG and PS performed all the usability tests. BB and MS analyzed the data and discussed the findings with all authors in various settings. BB was a major contributor in writing the manuscript, LGP, JK and SK contributed to the manuscript in forms of feedback and discussion of the content. All authors read and approved the final manuscript.

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Availability of data and materials

The transcribed data are not publicly available due to privacy restrictions but are available from the corresponding author on reasonable request. All screenshots of the CoronaMelder app are online available via Figma.

Ethics approval and consent to participate

The study was approved by the University's Ethical Committee (BCE200953). The BMS Lab protocol for corona-safe human-related research has been approved by the Executive Board of the University of Twente. Hands and technical equipment were disinfected before and after the tests and Dutch RIVM guidelines were followed. Participants were informed of the voluntary nature of their participation and confidentially was guaranteed. All participants signed an informed consent, the parent or guardian signed the informed consent for minors.

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Supplementary Files

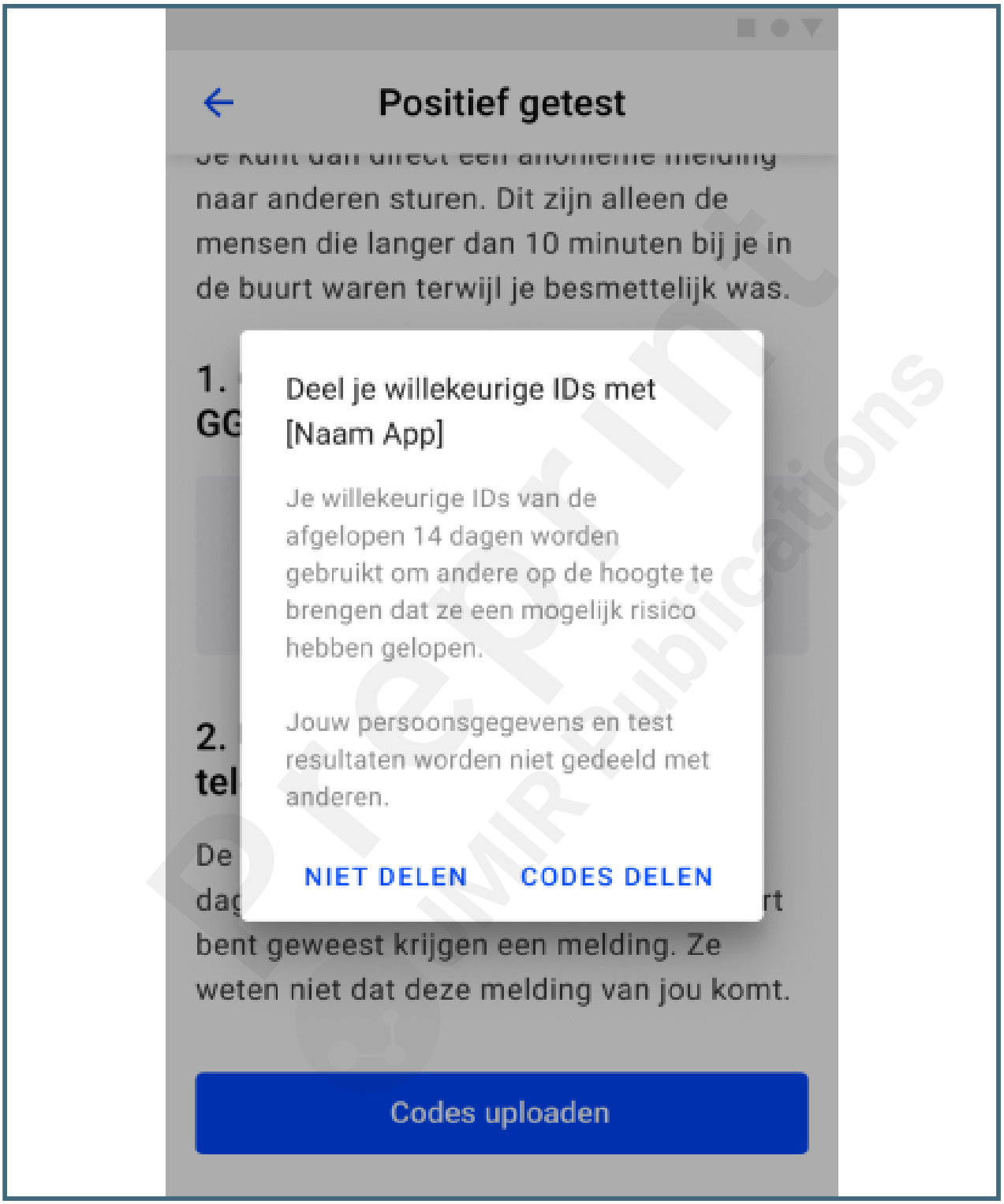
Figures

Screenshot of Frequently Asked Questions (Figure 7; 2*). Explanation about how the app guarantees anonymity.

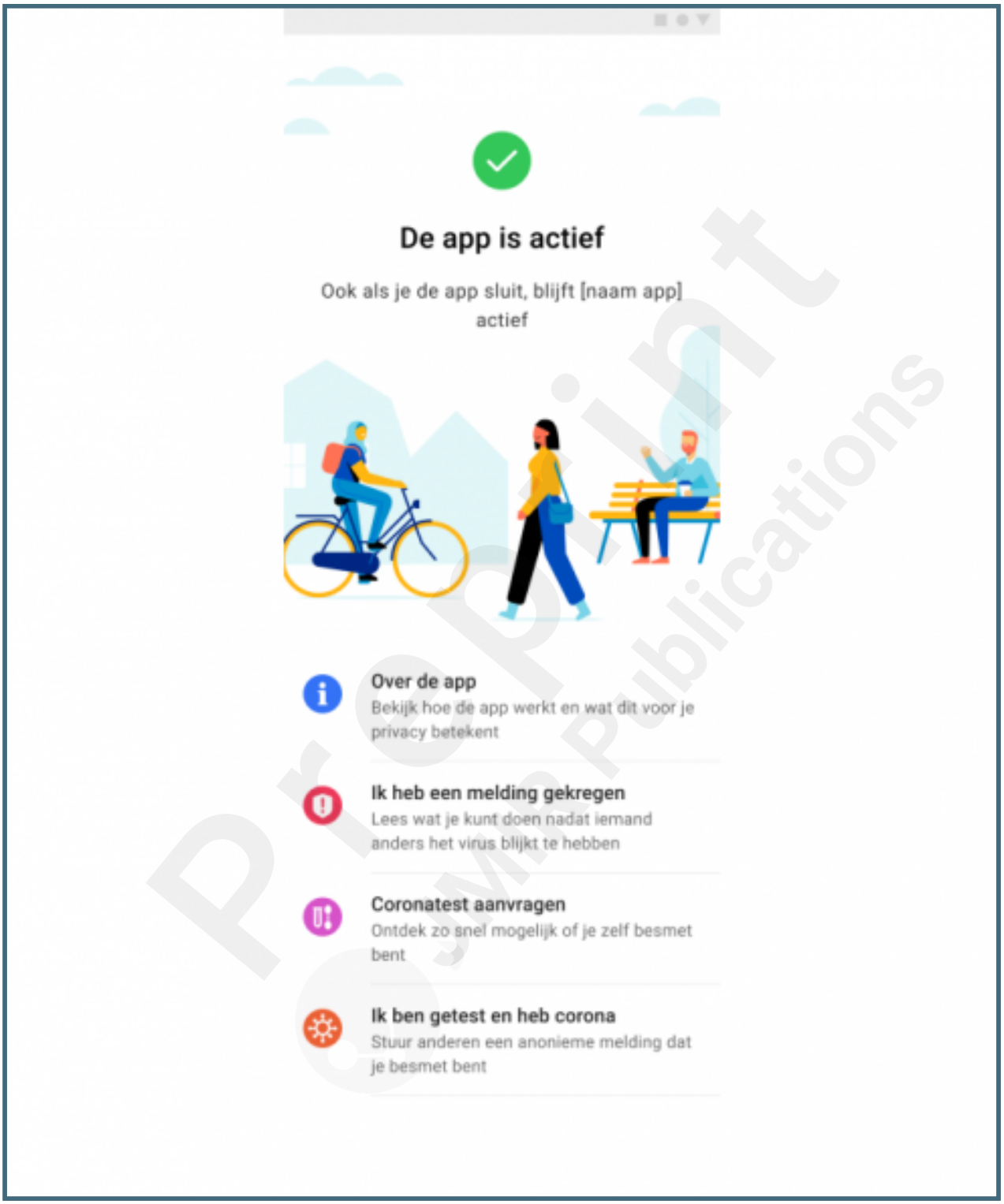
Explanation of how the app operates.

Screenshots of Frequently Asked Questions (Figure 7; 2*). Explanation that the app does not track GPS.

The notification which pop-ups after sharing the key (Figure 5; 2*), which asks the user for permission (to share or not to share) after they clicked on “share the key”.

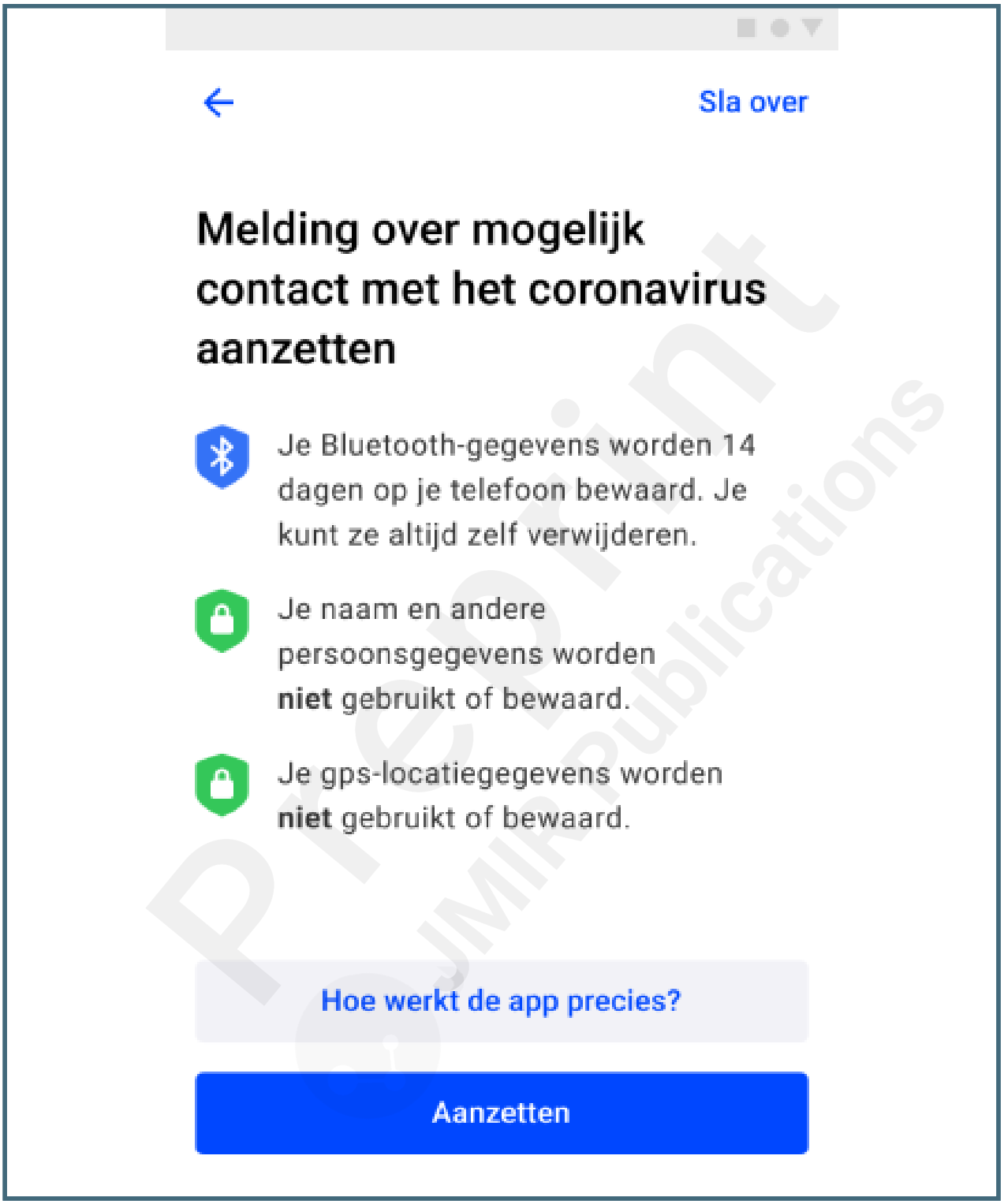


The app’s home screen which occurs after the onboarding steps are performed and the app is activated and ready for use.



Giving permission to receive notifications of the app.

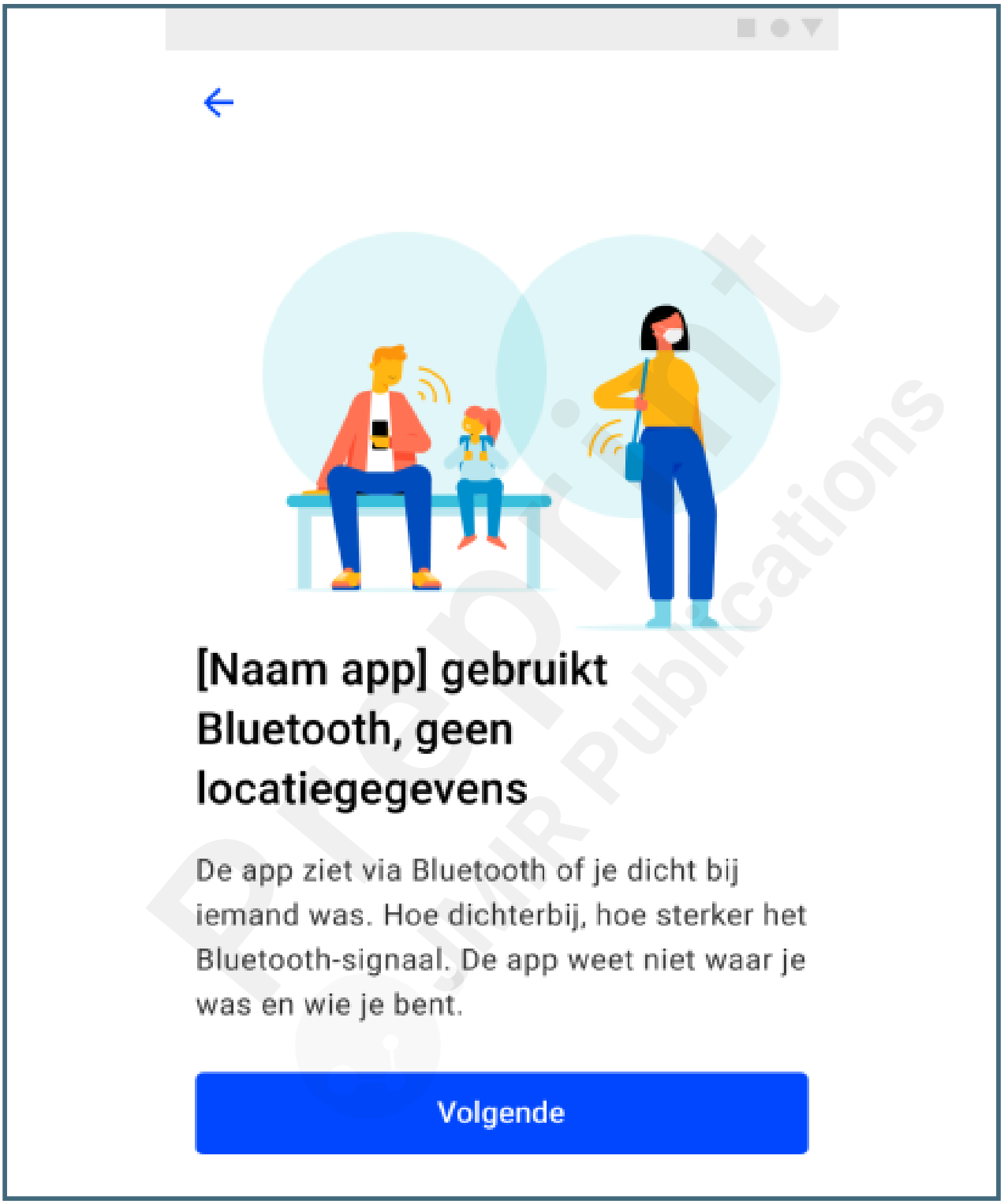
Giving permission to allow the app to use Bluetooth.



Example of when you will receive a notification (Figure 3).

Example of when you will not receive a notification (Figure 2).

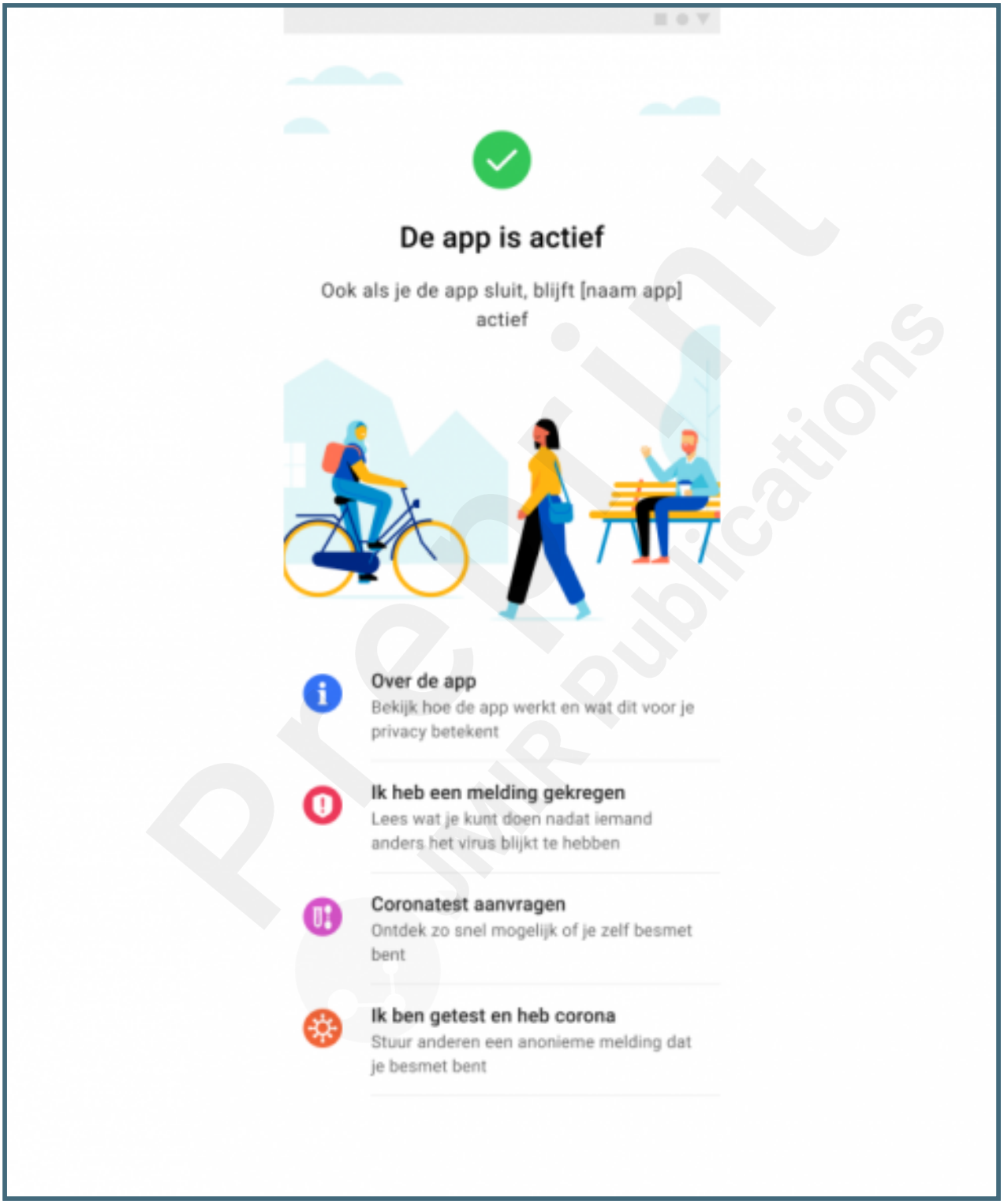
Explanation about how the app uses Bluetooth and no additional data.



When you will receive a notification.

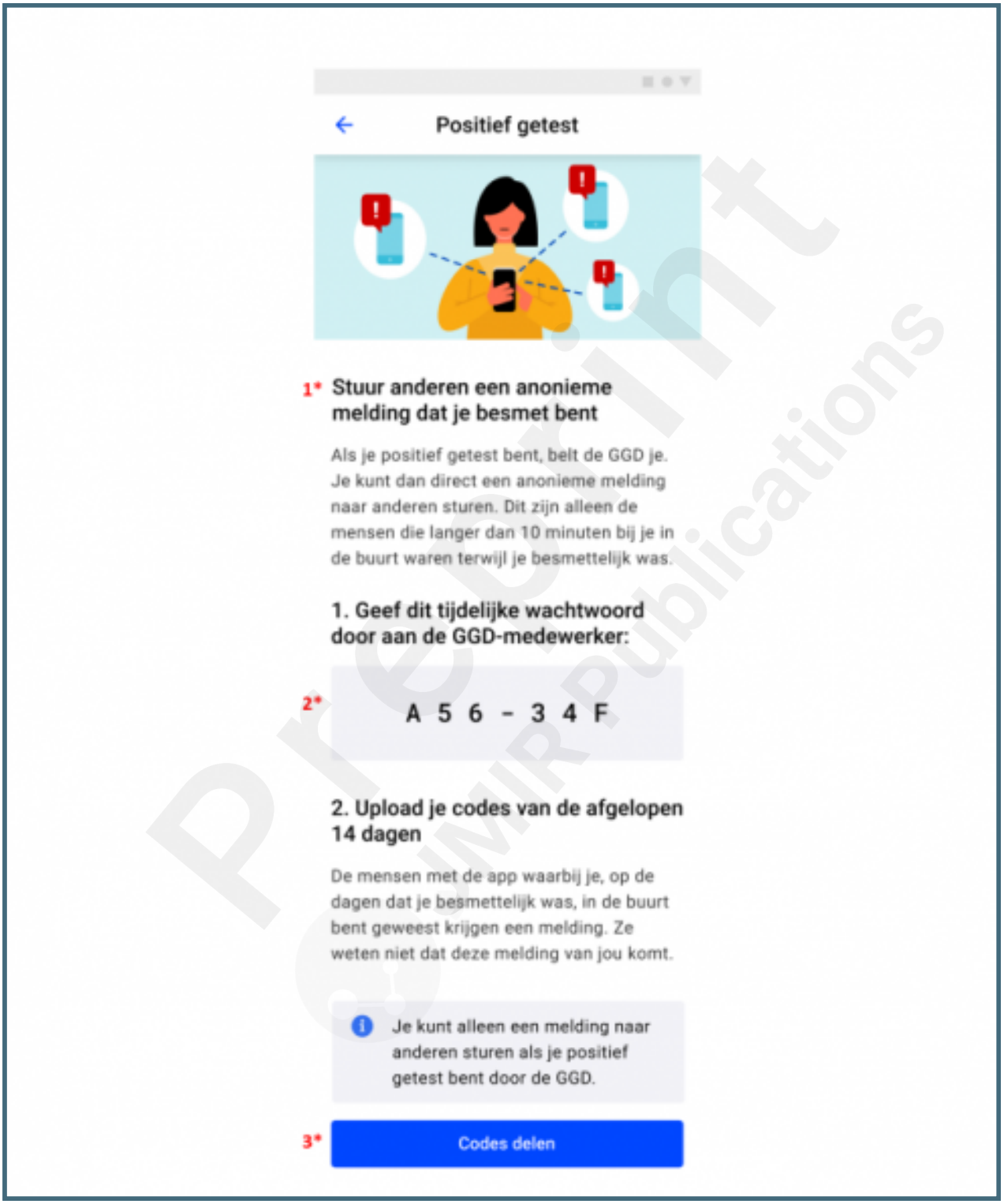
Start screen with Dutch COVID-19 combat slogan.

The home screen of the app, which displays after the user has finished the onboarding and activation of the app. At the top1* the app explains to be activated for use. Below, several information pages are displayed, such as: 2*Information about how the app works, 3*Information about what to do if you receive a notification (Figure 6), 4*Requesting a COVID-19 test, and 5*Positively tested (Figure 5).

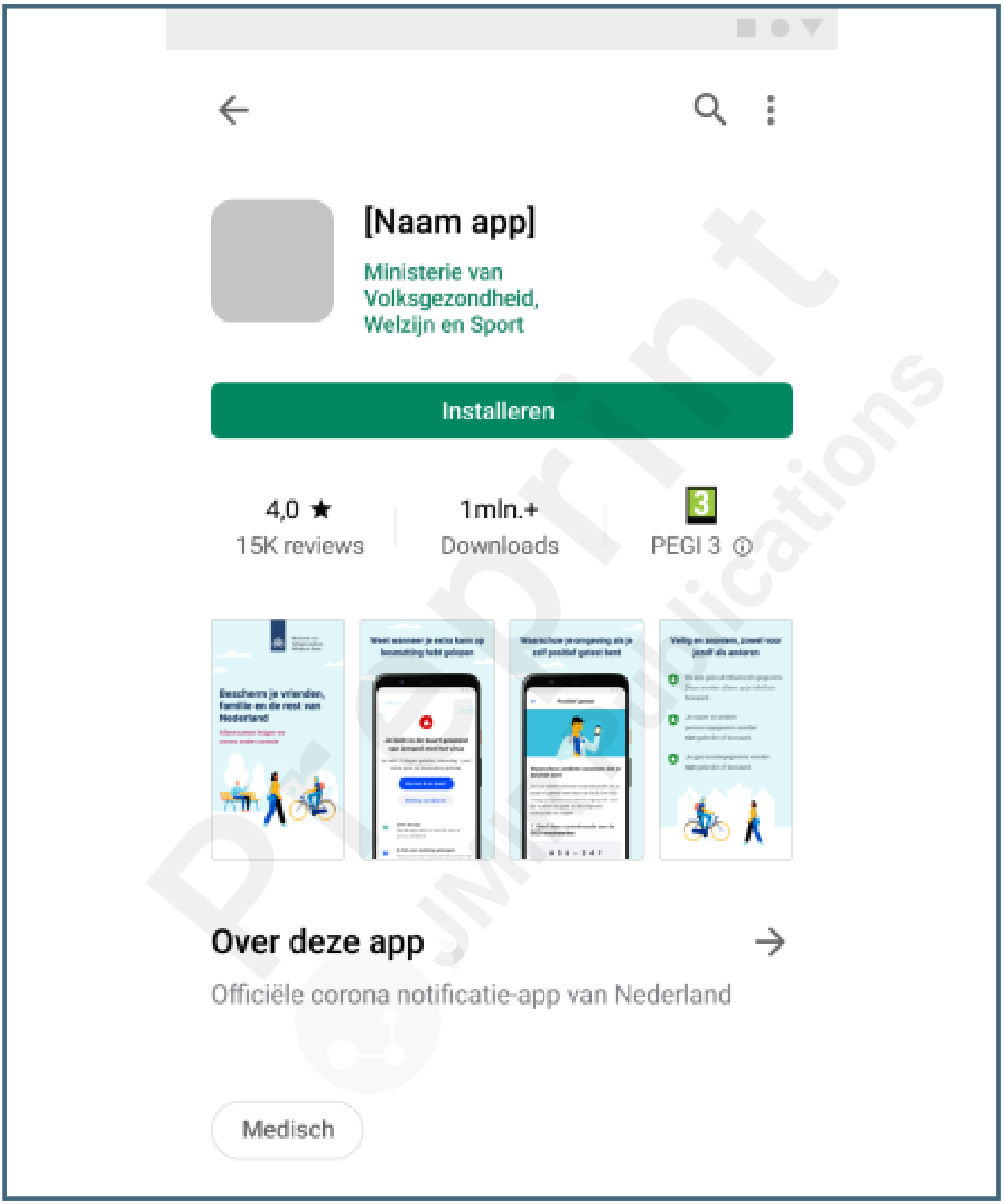


Screenshot of ‘Positive tested’ page. The text informs the user what to do after receiving a notification of being exposed to an increased risk. When users click on the button below 1*, a corona test can be quested in a telephone call.

Screenshot of ‘Positive tested’ page. The text informs users that they warn others anounymously1*. Users must mention the key2* to a PHA worker to validate their positive test. Afterwards, they must click on the ‘share key’ button3* to warn other app users they have been in contact with in the last 14 days.



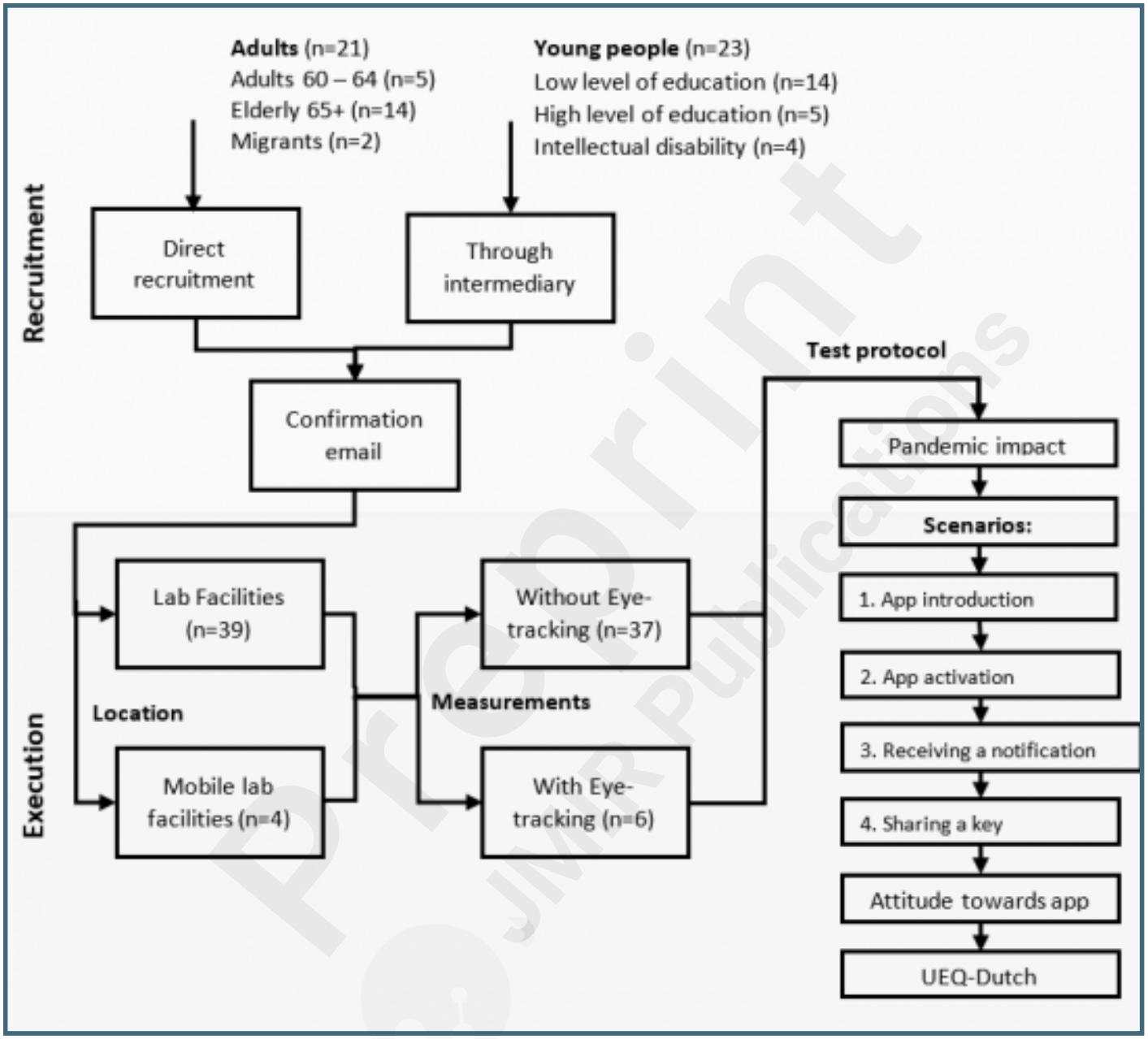
The app within the Appstore. The app can be installed when clicking on the button labelled with 1*. Additional information can be found under 2*.



Screenshot shown during the onboarding, with an example of when users are exposed to an increased risk. Translated as: “Were you too close to someone on the train? Then you can receive a notification later”.

Screenshot shown during the onboarding, with an example of when users are not exposed to an increased risk. Translated as: “Did someone cycle past you? Then you will not receive a notification later”.

Flowchart of study recruitment and procedure. The Top part visualizes the recruitment methods, through both direct (n=21) and indirect (via intermediaries/representatives, n=23) channels. Included participants were tested in a stationary and mobile lab, with or without additional eye-tracking, following the test protocol depicted on the right.



Multimedia Appendixes

PHA Telephone script for positive test results.
URL: https://asset.jmir.pub/assets/f1a862e646fb181d371b1c6a18fcb583.docx

Additional information about the CoronaMelder. A. Information accessible from the Appstore. The text provides information about: 1* the aim of the app, 2* how the app operates, 3* the (only) usage of Bluetooth, 4* when users receive a notification, 5* when and how to warn others, and 6* what makes the app safe and anonymously. B. Frequently Asked Questions accessible within the CoronaMelder app, such as: How can the app see my location7*, How can the app be anonymously8*, When will I receive a notification?9*, Can Bluetooth operate through walls?10*, and How much battery uses the app?11*.
URL: https://asset.jmir.pub/assets/d8d83cffa103e8f996f9129e1a83d4d6.docx

Table 4 in detail. Number of participants per target group who stated a positive or negative comment about the CoronaMelder, per topic (user-friendliness, understandability, reliability & credibility, and inclusiveness). In case of the understandability of the notification and sharing the key, the table shows how many participants understood the working of the CoronaMelder app.
URL: https://asset.jmir.pub/assets/c5ffc4fb726c9257495cf9e3b46530b6.docx

UEQ-Dutch.
URL: https://asset.jmir.pub/assets/50597d7a591958c8cec1d573ab4fd3fa.docx

Test protocol.
URL: https://asset.jmir.pub/assets/7236ba4e0347dbabb135b40a10dd7eb2.docx