


User perspectives and preferences regarding a mobile health cough application: A qualitative study during the coronavirus disease pandemic in Denmark

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Abstract

Introduction: Health care systems worldwide are currently facing major challenges because of the coronavirus disease pandemic. When individuals experience coronavirus disease symptoms, they often have to decide whether to seek health care services and render themselves vulnerable to infection or stay home and monitor their condition. Coronavirus disease management strategies should aim to reduce transmission, promote disease control, and facilitate self-monitoring within the population. In this regard, mobile health technologies serve as supportive tools, and acquiring knowledge about user perspectives will facilitate the development and integration of coronavirus disease-related applications. Accordingly, this study aimed to examine user perspectives on applications that monitor coronavirus disease-related physical signs and identify discrepancies between user expectations and developer design perspectives within the Danish context.

Materials and methods: A qualitative research design was adopted. Semi-structured telephone interviews were conducted to examine user expectations during the first wave of the coronavirus disease pandemic in April 2020. The theoretical framework, which was inspired by the concept of health literacy, was developed using a six-step thematic analytic approach.

Results: The analysis yielded two major themes that captured user experiences: (1) coronavirus disease-related applications may serve as digital tools that foster safety when physical signs are monitored and (2) the acceptability of coronavirus disease-related applications depends on the adoption of a personalised and user-friendly design.

Keywords

mHealth, Covid-19, UX research, health literacy, health monitoring, lockdown

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Introduction

Healthcare systems worldwide are currently facing major challenges because of the coronavirus disease (COVID-19) pandemic, for instance, hospital inpatient and intensive care bed capacity, as well as mutations that pose a threat to global immunisation efforts.¹ However, little is known about the disease mechanisms associated with COVID-19, and although vaccines have been developed, the long-term effectiveness of vaccines is still unknown.^{2,3} Therefore, COVID-19 management strategies

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should aim to reduce transmission, promote disease control, and facilitate self-monitoring within the population. This includes encouraging individuals to stay home as much as possible and promoting the practice of social distancing to prevent transmission and protect community health.^{4,5} In this regard, mobile health (mHealth) technologies serve as supportive tools. mHealth may facilitate self-monitoring among users who have been staying home and COVID-19-positive patients with mild symptoms who have been instructed to self-quarantine at home.^{4,6} Smartphones utilise high-quality technology and provide suitable platforms for the collection of real-time data, which users can store and share.^{7,8} Further advantages of mHealth interventions include cost-effectiveness to implement, as mHealth interventions are available to a large number of people because of a high number of individuals with internet-enabled devices.⁹ In addition, past studies have found that individuals living in the Western world are increasingly willing to use mobile phone applications to manage their health.^{9–12} Globally, several COVID-19-specific mHealth applications have been developed.^{13,14} These applications focus on different strategies: contact tracing/exposure notification, symptom monitoring and information provision.¹⁵ Most mHealth applications assess the symptoms experienced by users. This study was a part of conceptual progress in the development of an application (CoronaMonitor) that monitors objective COVID-19-related physical signs in users.¹⁶ Most of the other available COVID-19-specific applications focus on subjective symptoms. This study aimed to facilitate further development and integration of this application. We aimed to examine user perspectives and identify the motivators and barriers associated with the use of applications that monitor COVID-19-related signs within the Danish context. Specifically, we examined how such applications help individuals manage and monitor their condition. We also aimed to identify discrepancies between user expectations and developer design perspectives to determine if their visions were aligned.

Materials and methods

Design

A qualitative research design was adopted. Semi-structured telephone interviews were conducted to examine user expectations regarding applications that monitor COVID-19-related physical signs and developer expectations in Denmark. This article has been prepared in accordance with the consolidated criteria for reporting qualitative research (Appendix 1).¹⁷

The CoronaMonitor application

This study was a part of conceptual progress in the development of the theory-based CoronaMonitor

application, which monitors objective COVID-19-related physical signs in users. The application was developed as a collaboration between electronics engineers, scholars, physicians and nurses. Both symptoms and signs are abnormalities that are indicative of an underlying medical condition. Whereas signs are objective evidence of an underlying disease that can be observed by others, symptoms are subjective evidence rooted solely in patient experiences.¹⁶ The main symptoms of COVID-19 are cough, feelings of warmth, shortness of breath, headache, tiredness, a sore throat, and gastrointestinal issues.¹⁸ In contrast, objective signs include cough, especially dry cough, dyspnoea, fever and impaired consciousness. The primary aim of this application was to classify coughs as those indicative and not indicative of COVID-19 and assess cough frequency. Other physical signs were to be included later. The purpose of this application was to monitor objective COVID-19-related physical signs so that users can monitor their condition at home without rendering themselves and others vulnerable to infection (e.g. by visiting a general practitioner or hospital). CoronaMonitor generates a daily health status report using data regarding cough, breathing, heart rate and sleep. This application also assesses subjective experiences. Specifically, using free-text boxes, users can add symptoms, rate them and describe their condition. These data points reflect how citizens experience their physical signs and disease.¹⁹ This combination of objective and subjective data helps users track their health status over time. The CoronaMonitor application used in this study served as an example during the interviews, and participants were directly asked to state their expectations regarding the development of this application to determine if it is likely to meet the expectations and needs of future users.

Setting and participants

The present study was conducted during the first wave of the COVID-19 pandemic in Denmark. Denmark's Prime Minister introduced the first lockdown measures, starting on 13 March 2020. All public sector employees without critical functions were sent home on paid leave, while private sector employees were encouraged to work from home as much as possible.²⁰ Denmark is a highly digitised country with a strong welfare state, and it weathered the COVID-19 crisis with a relatively low infection and death rate during the first wave of the pandemic.^{20,21}

The authors shared the link to the survey through both individual and organisational social media platforms on LinkedIn and Facebook. Interested individuals completed a form including demographic information to express interest in taking part in the research. Participants were subsequently contacted by telephone by one of the researchers

who arranged the interview (see Appendix 2). The participants were purposefully sampled based on age, gender, educational level and occupational status (e.g. employed vs retired) to generate nuanced answers for the research questions.²²

Since the interviews were conducted during the lockdown period, the invitation and consent form were presented as a part of the survey created using Google Forms. In total, 33 individuals volunteered to participate in the study. Seven individuals dropped out because of their busy schedules, and three individuals had provided invalid telephone numbers. Thus, user perspectives were

examined using a sample of 23 individuals. Additionally, six developers with experience in developing complex application systems (scholars, engineers and leaders) were recruited. First, an invitation was sent to the Technical University of Denmark. Interested developers volunteered to participate in the study. They represented the field of mHealth technology, and their skill levels ranged from novice to expert. All the developers were employed at the Technical University of Denmark, which is the only institution of its kind in the country. Participant characteristics are presented in Table 1.

Table 1. Participant characteristics.

Group	Code	Gender	Age	Occupation
Users	U-1	M	56	Researcher
	U-2	F	78	Retired
	U-3	M	77	Retired
	U-4	M	71	Retired
	U-5	M	51	Retired
	U-6	F	69	Retired
	U-7	F	30	Project developer
	U-8	M	47	Project developer
	U-9	F	30	Researcher
	U-10	F	48	Researcher
	U-11	M	24	Student
	U-12	M	65	Retired
	U-13	M	42	Programmer
	U-14	F	43	Dentist
	U-15	M	20	Student
	U-16	M	21	Student
	U-17	M	18	Other
	U-18	F	20	Student
	U-19	M	26	Student
	U-20	F	46	Teacher

(continued)

Data collection

The interview procedure was guided by the qualitative interview method described by Clarke and Braun.²³ A semi-structured approach was adopted so that we could cover the interview topics as well as retain flexibility in the process.²³ Thus, questions not included in the interview guide were asked if new ideas occurred during the interview.²³ Individual telephone interviews were conducted using a pre-developed interview guide (see Appendix 3). HE and SK conducted user interviews between 1 and 23 April, 2021. Interview durations ranged from 17 min to 35 min. The interviews were conducted until sufficient depth and richness related to the research question were explored.^{22,23} All the interviews were audio-recorded on a digital voice recorder and transcribed verbatim after each interview by the researcher conducting the interviews. All the participants were anonymised using codes. Hereinafter, the letters 'U' and 'D' in participant codes denote users and developers, respectively (see Table 1).

Table 1. Continued.

Group	Code	Gender	Age	Occupation
	U-21	M	83	Retired
	U-22	F	33	Student
	U-23	F	36	Student
Developers	D-1	M	25	Scholar
	D-2	M	27	Scholar
	D-3	M	24	Engineer
	D-4	M	24	Engineer
	D-5	M	30	Leader
	D-6	M	24	Scholar

F: female; M: male.

Ethics

The project, 'Artificial intelligence-based smartphone monitor for the objective signs of COVID-19', was approved by the Danish Data Protection Agency (Journal No. 20-000012/052-2020) and the National Committee on Health Research Ethics. The study was conducted in accordance with the principles outlined in the Declaration of Helsinki.²⁴ Written informed consent was obtained from all participants.

Data analysis

To examine user experiences and analyse the interview transcripts, Braun and Clarke's six-step thematic analytic approach was adopted.²³ The six-step thematic analysis includes²⁵:

- familiarizing yourself with your data;
- generating initial codes;
- searching for themes;
- reviewing themes;
- defining and naming themes;
- producing the report.

Thematic analysis is an inductive approach that allows researchers to identify the patterns and themes that underlie qualitative data. This method is essentially independent of theory and epistemology.²³ Thematic analysis allows one to examine disclosed experiences and attitudes to construct common themes (e.g. topics, ideas and patterns of meaning) identified repeatedly.

To analyse and interpret the data, the transcripts were read and re-read several times during the initial coding process. Each interview transcript was coded line-by-line. The data were organised based on content, and faithfulness to the original narratives was ensured. The codes were collated into potential themes. Text that resonated with more than one theme was coded several times and assigned different codes. Mind maps were used to classify and visualise the themes. To ensure analytic rigour, the results of the analysis were critically reviewed and examined by HE and MB. Discussions were conducted among the five researchers to ensure that the contents of the main themes were consistent with the ideas discussed during the interviews. Each theme was analysed in greater detail to refine its essence and specific contents. Sub-themes were created to enhance the structure of each theme. The themes were phrased in such a way that readers immediately understand the essence of each theme.

The theoretical framework adopted in this study was inspired by the concept of health literacy, which Kickbusch et al have defined as follows:

The ability to make sound health decision(s) in the context of everyday life at home, in the community, at the

*workplace, the healthcare system, the market place and the political arena. It is a critical empowerment strategy to increase people's control over their health, their ability to seek out information, and their ability to take responsibility.*²⁶

Health literacy advocates aim to improve knowledge about health-related issues among citizens to promote empowerment and compliance. However, there are wide individual differences in health literacy because of heterogeneity in life circumstances, socioeconomic status and cognitive frames of reference.²⁷

Results

The analysis yielded the following two themes, which describe the factors expected to influence application use to monitor COVID-19 signs: (a) COVID-19-related applications may serve as digital tools that foster a sense of safety when physical signs are monitored, and (b) the acceptability of COVID-19-related applications depends on their adoption of a personalised and user-friendly design.

COVID-19-related applications may serve as digital tools that foster a sense of safety when physical signs are monitored

According to the participants, COVID-19-related applications have the potential to foster a sense of safety and autonomy. This is attributable to their expectation that such applications will serve as digital tools in their daily lives and provide them with an overview of their objective physical signs. For example, one participant made the following statement:

It may be a good idea with therapeutic aids. That it [the application] can come up with good advice based on what it measures, for example, 'Your temperature profile indicates that you should stay in bed'. (U-4)

The participants expected 'better' monitoring so that they could make more informed decisions about how they should lead their lives during the pandemic and understand how their physical signs should be interpreted. For example, a participant made the following comment:

I can better live my life . . . knowing if I need to be in quarantine. An application is supposed to give a better understanding of how much you can 'afford' to do without being at risk and how the disease develops. It should be able to measure the symptoms and conclude if you are at risk. (U-2)

Participant expectations of future applications were high and diverse. In particular, they wished to be independent when they monitored objective physical signs at home during the imposition of COVID-19-related restrictions. This was attributable to their expectation that such applications will inform them about the precautions that they ought to take in their daily lives, recommend therapeutic recourses, offer advice and provide feedback about their condition.

A corona application needs to have a diagnostic safety on the other side of 85%, give some warning, explain treatment strategies, inform about drugs, and be able to give you a warning in relation to when to contact your doctor. (U-4)

The participants reported that the application will foster safety by providing feedback based on the monitored physical signs. Thus, the participants were willing to divulge private information to gain a sense of safety. Physical signs will be assessed in accordance with user comfort considerations to validate their subjective symptoms. Thus, their physical signs and daily functions can be compared to their experiences of the subjective symptoms of the disease. They believed that an application that alters their perceptions of their health condition and alleviates their fear of infection will mitigate their worries and rectify an overestimation of the risk involved in interacting with others in a more factual manner. As the following excerpt illustrates, one participant believed that such an application will provide him with an overview of his health status:

I have a boyfriend with joint-custody children, and it raises awareness and worries every day. What if they come home with symptoms from their mothers? Then, we would expose ourselves to danger. The biggest concern is about the people you are forced to see, especially on days when you feel that you are about to be sick. (U-14)

This excerpt makes it apparent that the participants wished for an application that would inform them about how they can interact with others without rendering themselves vulnerable to COVID-19 transmission. Furthermore, they wanted the application to allow them to share the results of assessments of their physical signs with others and help them avoid social interaction. Fear of infection was a crucial concern among the participants. Therefore, they wanted an application that will monitor their potential physical signs, answer questions and provide feedback and guidance so that they feel calmer and more comfortable and do not have to contact a doctor if they experience any influenza symptoms. For example, one participant wanted the application to help

him gain nuanced insights into his symptoms and help him decide whether he should be concerned:

An application won't necessarily give me more security. But it would give me an input in relation to decision-making and legitimise my symptoms, in which I can show to my doctor and point out that I am at risk. Therefore, if it can give me a free ticket to my doctor, and I get a test done, it will give me greater confidence and the feeling of security, because I do not just get told that you can stay home for 14 days. (U-9)

At-risk and previously symptomatic patients perceived such applications as tools that would enable them to verify notifications about their health status and access healthcare services (e.g. test kits). One participant described how she imagined the application would communicate with her if she were sick in the following manner:

'Hey. . . we assessed your cough combined with your fever, and we think you should contact the doctor'. A dream scenario would be a button I can just press and then get an overview of who I need to contact and when to be tested. If I could be given direct access to being tested, because this application is validated, and I have some symptoms that make it easy for me to be tested, that would be great. (U-9)

With regard to their sense of safety, the participants noted that future COVID-19-related applications will not provide existential security but will serve as a platform through which information can be acquired to improve decision making. The participants elaborated that the application will foster a sense of safety by validating and providing information about symptoms. One participant offered nuanced insights into how applications foster a sense of safety by making the following observation:

I don't want to trust the safety of an application. Security is a very big concept in relation to an epidemic, whether it is Ebola or whatever it is. An app can appear in connection with other things, in the context with other things. . . if it is stand-alone, then it can also give a little insecurity, I think. (U-10)

Another participant made the following statement:

I don't know if it will make me feel safe, but it will give me an assurance that the strategy I have right now is the right one. It will provide security, but I would not use it as an indication of how healthy I am or whether I am sick or not. (U-11)

The participants expected future COVID-19-related applications to collect, sort and overview the available

information on COVID-19. For example, one participant made the following observation: *'It would be easier with an application, instead of turning on websites so you could use your phone to research the symptoms'* (U-7). Participants who had not used health applications previously considered COVID-19-related applications to be relevant because they may help systematise essential information. A participant described the diagnostic functions that an application should have in order for her to use it by stating the following:

Before I decide to use an application, I need to be informed and assured about how useful it will be to me and my family, for example, if it can identify the development of diseases [and] diagnose or predict prognoses. (U-4)

Furthermore, individuals with limited technical knowledge did not report any barriers to the use of such applications when the need arises. However, their willingness to use such an application depended on whether it would serve as a platform that provides information that (only) enhances decision making.

It sounds like a thing that could benefit the general health condition; so, I'll probably consider using it. In terms of using it myself (e.g. monitoring symptoms), I would be sceptical of letting an application rate more than my own common sense would do. (U-13)

The developers were questioned about whether a COVID-19-related application would foster a sense of safety in users. The developers were very concerned about whether the monitored physical signs were valid enough to yield trustworthy results. They expressed concerns about measurement accuracy and wondered if the quality of different mobile phones will distort the assessment results. However, if these challenges are overcome, user safety can be ensured. In this regard, a developer made the following statement:

It can provide comfort in the form of knowing about these symptoms and having some quantitative data, such as fever and the number of times you have coughed. If you can . . . you know . . . get it in black and white. (D-4)

At the same time, they also emphasised that the application should not be used to diagnose COVID-19.

I think providing a COVID-19 diagnosis is a very dangerous message to someone who may not be ready for that message . . . And that is also why it is important not to diagnose anything at all. I find it valuable if the app, based on cough analysis, could tell this person: 'Go to a doctor or contact the health care system'. Therefore, safety should

not lie in the app itself but more that now is the time to go to a doctor. (D-5)

Acceptability depends on the adoption of a personalised and user-friendly design

The participants expressed how important it was for them to acquire information about the COVID-19 pandemic and noted that they may use this information alongside a digital tool to monitor their physical symptoms. However, they reported that the acceptability of future COVID-19-related applications will depend on their ease of use and user friendliness. In this regard, a participant made the following statement:

The user interface must be intuitive, short, precise, simple, and understandable, and I will need some text and images that can supplement some factual information in order to use it. (U-7)

The participants believed that their own perceptions of their subjective symptoms will play an important role in the use of digital technology. Thus, easy navigation within an application and personalised overviews of temporal changes in physical signs were perceived as features of user-friendly digital technology. The participants wished to see these features in future applications, and they were perceived as key factors that influence user attitudes and acceptability of digital technology (e.g. monitoring COVID-19 symptoms). The following excerpt underscores the central role of the level of convenience and personalisation offered by an interface in the perceived user friendliness and relevance of an application.

An application needs only a few possible keys, maybe a bar where you can swipe to the opportunities so that you do not have to formulate and register all the time, but it has to become visual, and you can easily indicate your symptoms as well as get a picture of your previous health scale. (U-14)

Another participant made the following statement:

For example, I have asthma and would prefer if I somehow would be able to register that, maybe even very specific to me and my symptoms. How is my breathing during the day? Some days are better than others for those of us who suffer from COPD. . . Maybe you even could be categorised in a group with others with the same risk. (U-9)

The participants noted that user privacy and control will have to be compromised to provide information about general health care. The application may be perceived as

a surveillance tool when users are screened for objective physical signs (e.g. breathing). However, the participants expected to witness disruption to peace and quiet in daily life. Nevertheless, the participants were willing to use COVID-19-related applications because they were expected to help them monitor their health status and, consequently, provide peace of mind. The following participant response illustrates this point:

All the simple possibilities you get provides you some kind of peace in mind . . . even though you know that somebody might be watching you . . . when you know about corona disease, then you know how important it is to get started very, very early, which I think is very helpful with a corona application. (U-12)

The participants were willing to use an application that monitors COVID-19 signs despite the likelihood of privacy breaches; however, what was of crucial significance was who controlled when the user should be monitored. The participants were not willing to compromise their integrity with regard to the risk of surveillance, and the deciding factor appeared to be who retains control over whether the application is switched on or off. For example, one participant made the following observation: ‘I don’t like it. . . it will be too much monitoring if it has to run 24/7. It would be okay if you could turn it off and on as needed’ (U-20). When we asked the developers to name the factors that are important to the development and use of the application, they agreed with the user group and stated that the application should be easy to use and have an attractive design. One developer provided the following response:

The application must be easy to use, and intuitiveness is the most important feature. So, when they open it, there should be nothing confusing. It should have a few buttons, and all use scenarios should be easy to reach. Therefore, it should look a bit attractive and capture their interest in 5 s, despite the fact that it is actually an app not just made for fun but to capture some important symptoms that a patient may have. (D-5)

The most important factor, which was emphasised by all the developers, was data security. High awareness about protecting user data and preventing data sharing without user consent was evident. Assuring users about the privacy of their data was perceived to be extremely important for the success of the application.

. . . to guarantee or convince people that—after all, it’s up to the developers to make sure data doesn’t leave the phone—but, then, to communicate to the potential user that we do not use data for anything else . . . how do you get it communicated so that people believe in one? (D-1)

However, another factor was also reported. Specifically, one developer reported some level of uncertainty about data security because of the ongoing COVID-19 crisis and the resultant increase in research activity in this field.

There is some sort of atmosphere in both the research community and app developers and in the community that you can afford something more during a crisis, and what is just as important to me in this will be that you do not set a precedent for doing some things in relation to privacy, which is not okay and which one cannot vouch for. (D-6)

Evidently, the developers considered data security and user privacy to be important requirements for any upcoming application. They were aware that future users would ascribe high importance to such factors.

Discussion

This study was conducted to examine user perspectives on applications that monitor COVID-19-related physical signs and identify discrepancies between user expectations and developer design perspectives within the Danish context. Two themes were identified: (a) COVID-19-related applications can serve as digital tools that foster a sense of safety when users monitor physical signs and (b) the acceptability of COVID-19-related applications depends on their adoption of a personalised and user-friendly design. The first theme subsumed a key discrepancy: users wanted applications to be highly secure related to virus from the very beginning, whereas developers perceived the application to be in the development stage and that safety will be built and reinforced across time. The second theme underscored the need for an application that is personalised based on user needs, preferences, conditions and life circumstances related to data safety and privacy features. Safety was not an independent issue but rather an inherent subtheme or circumstance as a part-whole logic that influenced participants’ experiences in both themes.

In this study, there were individual differences in how the participants had been coping with the pandemic. This was reflected in their perspectives on mHealth in general. Some reported feeling nervous, stressed and anxious when others failed to take COVID-19 seriously. Similar trends have been observed in other international research studies. Specifically, it has been found that the pandemic has exerted a psychological and social impact and contributed to stress and anxiety related to social interactions.^{28–30} However, some participants reported no or little anxiety and, therefore, believed that the world was overreacting to the outbreak. Despite these differences in reactions, they all agreed on the need and demand for protection and safety from the virus and potential transmission. Owing to the imposition of the lockdown and social restrictions, virtual tools were perceived as tools that could help citizens

monitor their condition. The conclusions of a recent review entitled, *Wearable sensing and telehealth technology with potential applications in the coronavirus pandemic*, further support our results. Ding and colleagues reported that applications have the potential to support individuals during the ongoing pandemic. Furthermore, through remote monitoring, they reduce virus exposure, which benefits all individuals by increasing safety.³¹ These findings support our contention that such applications can provide different types of COVID-19-related information and serve as a bridge between the home and the outside world by facilitating remote monitoring among users.^{32–34}

According to Kickbusch et al., health literacy refers to the ability to make informed health decisions in daily life and plays an important role in increasing control over one's health.²⁶ Personal health technologies (e.g. applications) that generate health data in close proximity to individuals promote self-tracking and empowerment.³¹ Therefore, an application that is specially designed to monitor COVID-19-related physical signs may serve as an important contributor to health literacy among the public and potentially increase safety. Whether the application will reach its full potential and contribute to citizen safety remains a critical issue. According to our results, this depends on the ability of the application to effectively engage with diverse audiences with different health literacy levels and communication competencies. Among individuals with high health literacy, self-tracking may be the ultimate strategy that ensures self-control, but low health literacy may restrict one's ability to be an active participant. At the individual level, application use requires one to take on the responsibility of being aware of potential symptoms reported through an application.

Lomborg et al. have suggested that using self-tracking data for the benefit of users and the overall care sector requires the development of concrete ethical practices (e.g. interpretive aid) by health-care providers to help patients make sense of their self-tracking data.³⁵ Therefore, it is recommended that the COVID-19 application includes a hotline or provides access to an existing health-care provider (e.g. general practitioners or nurses) as these features would be helpful to users. Such applications are not alternatives to pre-existing professional assessment and counselling services. Instead, they should be perceived as digital tools that foster safety when physical signs are monitored and, consequently, a supplement to pre-existing assessment and counselling services.³⁵ In a recent editorial on digital healthcare during the COVID-19 pandemic, it has been suggested that applications offer diagnostic support and help individuals and communities cope with health crises, such as the COVID-19 pandemic, by enabling individuals to stay informed, feel more safe and lead their lives in a socially responsible manner.³⁴

In this study, the participants expected the mHealth application to foster a sense of safety, be easy to use and

ensure data privacy and safety because these characteristics are important to end-users. However, similar to the findings reported by Lomborg et al., concerns about data accuracy, a lack of trust in technology and uncertainty about user ability to interpret symptoms and changes in their health condition were reported as major barriers to future application use.³⁵ Therefore, health literacy is a major communication issue that is relevant to effective application use. Indeed, it refers to the ability to accurately interpret and utilise relevant health information and resources to achieve health goals. Thus, application developers should be cognizant of the health literacy levels of their target population and ensure technical face validity when they develop COVID-19-specific mHealth applications.

Our findings suggest that individuals will be interested in and willing to use such applications because they not only increase their ability to maintain social relationships but also ensure that they are not completely disconnected from each other. Given the ongoing COVID-19 pandemic, the participants believed that there are several reasons for individuals to voluntarily use a monitoring application. The application may facilitate social interaction among those who are particularly vulnerable to COVID-19. Similar to past findings on self-monitoring, our results indicate that individuals are willing to share personal health data when they receive valuable information in exchange.^{36,37} Figure 1 illustrates the main points embedded in this discussion.

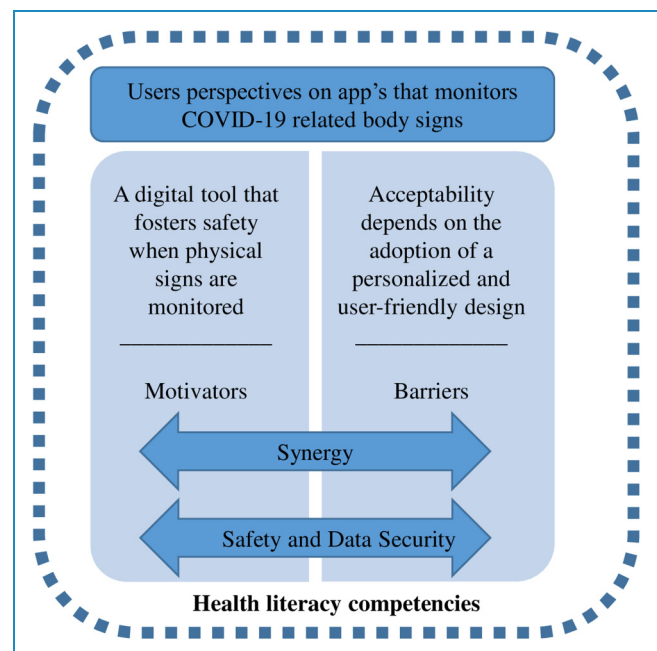


Figure 1. An illustration of the identified themes (safety and acceptability), perceived motivators and barriers associated with application use, and the role of health literacy in future adoption. COVID-19: coronavirus disease.

Strengths and limitations

The present findings will be of interest to application designers and health agencies because these preliminary results have implications for the development of a wide range of applications related to COVID-19. The study might influence future research as the findings exemplify qualitative insights gained when integrating user experiences in mHealth development phases. For practice, the study adds knowledge on potential concerns related to mHealth among the population and why some people refuse to adapt mHealth.

Some may consider telephone interviews to be a poor qualitative data collection method because body language data cannot be collected. However, this approach allowed us to address the aims of this study.³⁸ Telephone interviews facilitated open and free discussion with participants across the country. Thus, we were able to generate a rich dataset from a heterogeneous sample, and this may not have been possible if we had used the survey method.³⁹ We examined the perspectives of only those who had indicated their interest in participating in this study on social media platforms. We did not examine the perspectives of those without social media accounts, those who may have been sceptical about this study and those incapable of using digital tools. Another potential limitation is the small number of interview participants. However, recruiting a higher number of participants does not ensure quality.²² These results are also dependent on the local impact of the pandemic in Denmark. Finally, this study focused on an application that is under construction; therefore, some of its technical specifications, such as the following, remain unknown: whether and how such an application would be helpful when a majority of COVID-19 patients are asymptomatic, how accurately the application will determine cough frequency if several family members cough, and whether the application will be effective when new variants of the virus that causes COVID-19 emerge.

Conclusions

In total, 29 semi-structured interviews were conducted. Specifically, 23 and six interviews were conducted with users and developers, respectively. Overall, the participants reported positive attitudes towards the proposed monitoring system for future COVID-19-related applications. Two main themes captured participant expectations regarding future COVID-19-related applications: (a) COVID-19-related applications may serve as digital tools that foster safety when physical signs are monitored, and (b) the acceptability of such applications depends on the adoption of a personalised and user-friendly design. Most of the concerns shared by the participants can be addressed by determining whether they have been infected. The perceived importance of protecting the privacy of users who

are monitored through COVID-19-related applications was more pronounced among the developers than among the users. Most participants differed in their needs and boundaries regarding the use of applications that monitor physical signs. However, the present findings underscore the need for customisability and the importance of involving users and understanding their expectations when developing COVID-19-related applications to ensure privacy and user friendliness.

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Guarantor: STH

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Appendix 1. Consolidated criteria for reporting qualitative research

Adapted as original from Tong A, Sainsbury P and Craig J. Consolidated criteria for reporting qualitative research (COREQ): a 32- item checklist for interviews and focus group. *Int J Qual Heal Care* 2007; 19:349–357. ¹⁷

Table A1. Consolidated criteria for reporting qualitative studies (COREQ): 32-item checklist.

No item	Guide questions/description
Domain 1: Research team and reflexivity Personal characteristics	
1. Interviewer/facilitator	Which authors conducted the interview or focus group?
2. Credentials	What were the researcher's credentials? For example, PhD, MD
3. Occupation	What was their occupation at the time of the study?
4. Gender	Was the researcher male or female?
5. Experience and training	What experience or training did the researcher have?
Relationship with participants	
6. Relationship established	Was a relationship established prior to study commencement?
7. Participant knowledge of the interviewer	What did the participants know about the researcher? For example, personal goals, reasons for doing the research
8. Interviewer characteristics	What characteristics were reported about the interviewer/facilitator? For example, Bias, assumptions, reasons and interests in the research topic
Domain 2: study design Theoretical framework	
9. Methodological orientation and Theory	What methodological orientation was stated to underpin the study? For example, grounded theory, discourse analysis, ethnography, phenomenology, content analysis
Participant selection	
10. Sampling	How were participants selected? For example, purposive, convenience, consecutive, snowball
11. Method of approach	How were participants approached? For example, face-to-face, telephone, mail, email
12. Sample size	How many participants were in the study?
13. Non-participation	How many people refused to participate or dropped out? Reasons?
Setting	
14. Setting of data collection	Where was the data collected? For example, home, clinic, workplace
15. Presence of non-participants	Was anyone else present besides participants and researchers?
16. Description of sample	What are the important characteristics of the sample? For example, demographic data, date

(continued)

Table A1. Continued.

No item	Guide questions/description
Data collection	
17. Interview guide	Were questions, prompts, guides provided by the authors? Was it pilot tested?
18. Repeat interviews	Were repeat interviews carried out? If yes, how many?
19. Audio/visual recording	Did the research use audio or visual recording to collect the data?
20. Field notes	Were field notes made during and/or after the interview or focus group?
21. Duration	What was the duration of the interviews or focus group?
22. Data saturation	Was data saturation discussed?
23. Transcripts returned	Were transcripts returned to participants for comment and/or correction?
Domain 3: analysis and findings Data analysis	
24. Number of data coders	How many data coders coded the data?
25. Description of the coding tree	Did authors provide a description of the coding tree?
26. Derivation of themes	Were themes identified in advance or derived from the data?
27. Software	What software, if applicable, was used to manage the data?
28. Participant checking	Did participants provide feedback on the findings?
Reporting	
29. Quotations presented	Were participant quotations presented to illustrate the themes/findings? Was each quotation identified? For example, participant number
30. Data and findings consistent	Was there consistency between the data presented and the findings?
31. Clarity of major themes	Were major themes clearly presented in the findings?
32. Clarity of minor themes	Is there a description of diverse cases or discussion of minor themes?

Appendix 2. Interview invitation and consent

Interview invitation

Exploring citizens' wishes and needs for technology and monitoring solutions of COVID-19

Dear Participant

We are a group of 15 experts from all over Denmark, who have joined forces to help the Danes to monitor their health during the COVID-19 epidemic. Our group consists of physicians, developers, nurses, process people and economists working together to develop an app for monitoring the symptoms of COVID-19. Please read further about the app here: www.CoronaMonitor.dk

Background of the project

To supplement the limited number of tests that are present in the healthcare system, we are working internationally on technological solutions that can help diagnose the virus. There are a number of places to get information about symptoms and places where you can tell about your experiences with the disease. However, we want to develop an app that can monitor you and your body signs at home without being at the risk of infection for others. CoronaMonitor is unique in the sense that it measures your body and tells you about day-to-day changes. At the same time, you can choose to share your data with us, so we can follow how the epidemic develops and make the app even better.

We hope to be able to help you stay at home in a safe environment longer so that you are not exposed to unnecessary infection outside home. Hopefully, we can identify so-called biomarkers that can measure if you are infected before you even become aware of it. However, there is a lack of research-based knowledge about what wishes and needs users have in order to find it useful.

Your participation

You will contribute to the project via a telephone interview of approx. 30 min. The purpose of the interview is to investigate the expectations, wishes and needs you might have as a potential user of an upcoming COVID-19 monitoring app to find the app useful. Next, we want to gain knowledge about what aspects are meaningful to you when, as in the case of a CoronaMonitor, you need to interact with technology related to potential illness.

Anonymised data

All data registered during the project will be stored and analysed in an anonymised form. Data from the project will also only be published or passed on in anonymised form.

Further information

We hope that with this information you have gained a sufficient insight into what it means to participate in the project and that you feel equipped/ well informed to make the decision about your possible participation. You are welcome to contact the project staff as well as the scientific staff for further information.

Declaration of consent

I have received written information and I know enough about the purpose, method, advantages and disadvantages of saying yes to participating. If, after the end of the project, I want information about the results obtained in the project, I agree to contact the person responsible for the experiment to have these handed out. By completing this online form, I consent to participate in the research project.

To participate, please complete the form:

**Fields marked with an asterisk (*) are required*

1. Your Name: *
2. Your age: *
3. Your profession: *
4. Your Zip code: *
5. Your nationality (if other than Danish, please write your previous nationality as well) *
6. A telephone number on which we may contact you *
7. Preferred time that you want to be contacted. (e.g. between 15: 15–18: 45) *

Thank you for your contribution. We will contact you at the specified time.

Appendix 3. Interview guides

The interview guide – Users

Intro

Please tell me about how the current (COVID-19) situation is like right now?

Baseline before COVID-19

How do you (normally) use your phone in relation to your health?
Which health-related apps are relevant to you?

During COVID-19

Have you downloaded any new apps to your phone in relation to COVID-19?
If you were experiencing symptoms of virus, how would you react?
How do you experience your options to identify if you have COVID-19?

Try finish these sentences:

To me the COVID-19 virus means ...
If I have symptoms of COVID-19 I would...
In relation to the COVID-19 virus, technology, for example, apps would ...
The biggest challenges in using COVID-19-related apps is ...

Information on the CoronaMonitor app:

We are currently developing an app that can monitor you and your COVID-19 symptoms at home without infecting others. The CoronaMonitor app is unique in that it measures your body signals and tells you about day-to-day changes. At the same time, you can choose to share your data with us so we can keep track of how the epidemic is evolving and make the app even better. With the app, we hope to help you stay home in a safe environment longer so that you are not exposed to unnecessary contamination outside your home. Hopefully, we can identify so-called biomarkers (for instance cough) that can measure whether you are infected before you even realise it.

What is your immediate reaction to such an app?
Which expectations would you have to such an app?
In your opinion, what is most important in relation to the use?
How would you describe your motivation to use such an app?
Which data would you have in a COVID-19-related app?
What is the biggest challenges in relation to such an app?

Outro

Is there anything else you want to say in relation to the COVID-19 situation right now?
How has it been participating in this study?

The interview guide – Developers

Intro

Please tell me about how the current COVID-19 situation is like right now?

Baseline before COVID-19

What were your primary tasks before COVID-19?
Have you engaged with mHealth apps before? If you have, what were the primary objectives?
Try thinking of the time before COVID-19:
Which mHealth apps did you find relevant?
What did you expect regarding the public application of mHealth apps?

During COVID-19

Have your tasks changed after COVID-19? Do you have an example?

Can you please describe the difference on your tasks before COVID-19 and now? Do you have an example?

Have you added new apps to your smartphone as for COVID-19?

How do you experience the populations' opportunities to identify if they are infected with COVID-19?

The CoronaMonitor app

Can you please tell me about your work building the CoronaMonitor app?

What are your initial thoughts on the app?

What is the intention with the app?

Why did you choose to collaborate on the app?

What are your expectations for the app?

In your opinion, what is important related to the app for people to use it?

What do you suggest as major issues when using the app?

COVID-19 apps in general

What is the most important to you on the work with COVID-19 apps?

Do you expect that an app (e.g. CoronaMonitor), which monitor different body signs, can provide safety among people related to their health? Why?

What types of data do you think that people want to share with COVID-19 apps?

What are your expectations on future COVID-19 apps?

How do you think people will use the COVID-19 apps?

In your opinion, what is the greatest challenge in the development of COVID-19 apps?

Try finish these sentences:

To me, COVID-19 means that....

Related to COVID-19, technological solutions like apps mean that....

To me, the major challenge related to building a COVID-19 app is....

Outro

Is there anything we have not touched upon that you would like to add?

How has it been to participate in the interview?

Thank you for your participation.