Journal of Visual Language and Computing

journal homepage: www.ksiresearch.org/jvlc

YouCare: a Cross-platform Telehealth App for COVID-19

Gennaro Costagliola[a], Mattia De Rosa[a,*], Vittorio Fuccella[a] and Francesco Vitale[a]

[a]Dipartimento di Informatica, University of Salerno, Via Giovanni Paolo II, 84084 Fisciano (SA), Italy

ARTICLE INFO

Article History:
Submitted 4.23.2021
Revised 5.20.2021
Second Revision 7.30.2021
Accepted 8.15.2021

Keywords:
COVID-19
telehealth
app

ABSTRACT

The COVID-19 pandemic has caused disruption across the globe and put pressure on healthcare systems. In order to limit the use of hospital resources, the use of home care and telehealth has been very important to minimize direct human intervention in monitoring patients. The purpose of this work is to present YouCare: a cross-platform application that allows the collection of medical data on the health status of the user in order to allow physicians to efficiently monitor the status of the patient. As an important feature, it includes functions to monitor the general situation through statistics and interactions with the other users of the application. This might make the isolation period less stressful while exchanging current COVID experiences. The use of the application has been experimented with a usability test, obtaining positive feedback from the users. We also report other similar applications that have been developed and used in different parts of the world.

1. Introduction

The COVID-19 pandemic, which spread in Wuhan (Hubei, China) in the early 2020s, caused a major change worldwide, strongly influenced people's lifestyle, and put a lot of pressure on national health care systems, in some cases leading them to collapse (with shortages of both hospital beds, doctors and medical supplies such as masks and oxygen [30]). In a substantial part of the world, therefore, great efforts have been made to improve the situation of healthcare systems, on the one hand, by expanding the capacity of hospital systems, although necessarily limited, and on the other, by expanding the use of home care and telehealth. In the most critical cases, the lack of healthcare personnel (or even just phone contact with a physician) has also negatively affected home care, so systems that can minimize the need for direct human intervention in monitoring patients at home can prove very valuable. However physicians' positive communication skills have a significant psychological effect on COVID-19 patients [2], so limiting direct interaction between patient and health professional may be negative from that perspective. Moreover, for such patients, in addition to the disease, typically a quarantine at home is imposed as well. Obviously, such a state of isolation and the consequent lack/reduction of social interactions and information about the disease can negatively affect mood.

The purpose of this work is to present YouCare: a cross-platform application (Android / iOS / Web, in order to ensure the widest possible availability), to allow the collection of medical data about the health status of home patients in order to efficiently allow physicians constant monitoring of the patient's status (also providing alerts in the case of critical values). The application also provides some features intended to make the isolation period less stressful.

In particular, the user can fill out a questionnaire in which he/she reports his/her clinical data (body temperature, sore throat, headache, muscle pain, nausea, cough, shortness of breath, bad mood, oxygen saturation level, breathing rate, heart rate, and blood pressure). Moreover the user can get in direct contact with other users through a Forum section, in this way other users (often in similar situations) can offer practical help and support through reply messages. In addition, the user can check statistics about the use of the app and aggregate information about other users' daily questionnaires (so he/she can monitor the condition of the majority of users, to have an idea of the global situation). The user may request a phone contact as well. The person's emotional state may also benefit from the opportunity to interact with health

*Corresponding author
gencos@unisa.it (G. Costagliola); matderosa@unisa.it (M. De Rosa); vfuccella@unisa.it (V. Fuccella)
ORCID(s): 0000-0003-3816-7765 (G. Costagliola); 0000-0002-6922-5529 (M. De Rosa); 0000-0003-3244-3650 (V. Fuccella)

DOI reference number: 10.18293/JVLC2021-N1-009

professionals and other people who are affected by COVID-19 and the ability to track overall statistics. The app also allows the user to "manage" another person, e.g. an elderly relative who does not have or is unable to use a smartphone or pc.

This paper is an extended version of work published in [12]. We extend our previous work by expanding the empirical evaluation to older people.

The paper is organized as follows: Section 2 describes previous work on COVID-19 apps; Section 3 describes the YouCare application, Section 4 shows its experimental evaluation, and Section 5 the evaluation results. Finally, Section 6 concludes the paper with a discussion on future work.

2. Related Work

Since the onset of the COVID-19 pandemic, numerous technologies and mobile applications have been proposed. Great interest has been devoted to contact tracing apps, with the study of different technologies and architectures, each with different privacy implications [1]. The use of this kind of technology has not been limited to contact tracing, but uses for telemedicine and remote diagnosis have also been explored, since in recent years, devices such as smartphones, smartwatches, and smart bands have seen an increase in usage in the medical and assistive technology fields [19, 10, 31, 4]. Some contact tracing apps have also included such features [3]. In this section, we will briefly focus on applications that offer these functionalities.

Among COVID-19 contact tracing apps, some include the ability for the user to report their health status (self-assessment). As an example, COVID Tracker is an app used by the Irish Health Service Executive for contact tracing on a national basis [14]. COVID Tracker monitors contacts between nearby devices via Bluetooth. Upon detection of contact with a positive, it alerts affected users via anonymous notifications. If the user expresses consent, instead of notification, they can receive a direct phone call from a health care provider. Daily, the user can fill in a short questionnaire in which he/she communicates his/her health situation based on a few parameters (fever, breathing problems, cough, taste, and smell problems). This application also has an informative side, in fact, on the homepage the citizen can read statistics on the progress of the infection in Ireland. Among the available statistics, there are: number of installations of the application, number of tests performed, number of symptomatic and asymptomatic infected people. Other examples of applications that include the facility for self-assessment used in different parts of the world include Mawid (Saudi Arabia) [5], Aarogya Setu (India) [18], NHS COVID-19 (UK) [23], PathCheck SafePlaces (USA) [24]. Another case is the Health Code system for contact tracing that has been integrated in China into two of the most popular apps used by the population, WeChat and Alipay [22]. According to the health code rules peoples are required to enter their personal information, including medical and health status information, into these apps. Based on contact tracing and entered symptom information the app assigns a health risk status to the person, which regulates his or her movement options and the possible need for medical/health intervention.

Other applications, on the other hand, are designed explicitly to allow the user to report their health status, both in the case of people without a COVID-19 diagnosis (preventive monitoring) and people with a COVID-19 diagnosis (home care). As an example, the Cvm-Health [27] web app, distributed by Sensyne Health in the UK and US, is a COVID-19 monitoring app. Users can sign up for the platform and daily record their vital signs and any COVID-19-related symptoms. The app creates a personalized digital medical record based on the recorded vital sign data and symptom information. This app also offers a social aspect: it allows users to help family and friends who are digitally disconnected by monitoring their health. The platform interacts directly with the NHS (UK National Health System) by sharing the data entered by users. Another example is the e-Covid SINFONIA app [28], used in Campania (Italy), which notifies the user of the outcome of COVID-19 tests performed in regional laboratories, and also allows the user to submit a questionnaire with the main infection indicators. These data are then made available to the general practitioners. Within the application, it is possible to register family members in order to view or receive notifications of their test results. Other examples include [8] in which teleconsultation is performed through a mobile application, tablet, or web browser, and [20] in which the approach of the Cleveland Clinic incorporates a self-monitoring app for patient engagement, monitors symptoms for early intervention.

Some applications, in addition to self-reporting capabilities, make use of wearable devices to detect the person's vital signs [7]. Examples include [16], where wearable devices were used to collect vital signs of people in quarantine, e.g., before or after a trip abroad. This data is monitored by algorithms and a medical team so that signs of deteriorating health can be detected and people can be transferred to a hospital if necessary. In [15], instead, wearable devices were used to monitor patients with chronic illnesses or who are recovering from a COVID-19, so that some patients who would have to be hospitalized could be allowed to stay at home instead. Another example is the ZCare Monitor [32], a home monitoring system for COVID-19 patients in the non-acute phase developed by the Zucchetti Group in collaboration with Doctors Without Borders for the Lodi Hospital, among the first to address the health emergency related to Coronavirus, and used by 11 different hospital facilities, for a total of more than 10,000 patients . The center contacts COVID-19 positive patients who are quarantined at home by phone. Patients, daily, enter their physiological data through the platform. In addition, a pulse oximeter, connected via Bluetooth, sends the following data to the platform twice a day: body temperature, blood saturation level, maximum blood pressure, pulse, and heart rate. This data is collected directly by the hospital platforms and monitored daily, also with the help of software for predicting clinical status (using machine-learning algorithms).

Other research has focused on the possibility of using mobile devices for diagnosis. As an example, in [21], the authors discuss the pre-symptomatic detection of COVID-19 using smartwatch data, also focusing on asymptomatic patients. Given that the asymptomatic status of the disease does not preclude the possibility of infection, it would be helpful to know about this condition. The authors asked study participants to record daily symptoms and share fitness tracker data. The types of data collected included heart rate, steps, and sleep over a period of several months. Two infec-tion detection algorithms (RHR-Diff and HROS-AD) were developed, and based on these data, it was analyzed that 63% of COVID-19 cases could be detected prior to symptom on-set via a two-level alert system based on the occurrence of extreme increases in resting heart rate relative to the individual baseline. Such an alarm would allow, even several days in advance, the recognition of a possible asymptomatic in-fection and the ability to proceed with standard tests. Other examples include *AI4COVID-19* [17], in which a preliminary COVID-19 diagnosis is performed from cough samples captured through the app, and [25], an app that collects self-reported symptoms, diagnostic testing results, and smartwatch and activity tracker data. This data, collected over time, is used to help identify subtle changes indicating an infection.

3. YouCare

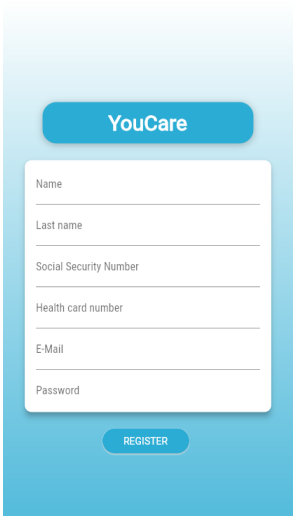
YouCare consists of three components: a cross-platform mobile application (Android/iOs/Web) used by the system's users, a server that receives/responds to requests from that application and stores user data, and a web platform that allows authorized physicians to access their patients' data. Based on what has been seen in the literature and from interviews with healthcare professionals and COVID-19 patients, the functional requirements of the application have been defined. Specifically, the application must allow:

- Registration and log in. The unauthenticated user must be able to login into the app. There must also be the ability to subscribe themselves. The app functionalities should only be available to people who have COVID-19 (or people with suspected COVID-19 and with a scheduled test or waiting for a test result).
- It should be possible to use the app's functionalities on behalf of another person. This is very important given the lower penetration of digital technologies among older people, who are also the category most at risk for COVID-19.
- Symptoms entry and statistics. The user must be able to enter his physiological data, useful for diagnosis, directly in his user area of the system on a daily basis. The application must allow the filling in of the questionnaire also for other users registered as relatives. The user shall also be able to consult global statistics about the users of the system.
- Forum. The user should have access to a Forum section in the application where he can read the topics of other users, reply to the topics and create his own. This should be possible in an anonymous way, possibly even restricting the geographic area in which messages can be viewed.
- Telephone support. The user should have the option of requesting telephone assistance. These requests will be handled by healthcare providers who, by accessing the request list, can make phone calls to the application users.
- View of users' status. The physician accessing the system with his credentials (provided by the administrator) can view the data collected with the questionnaires of his patients. Alerts and statistics about his patients should also be available.

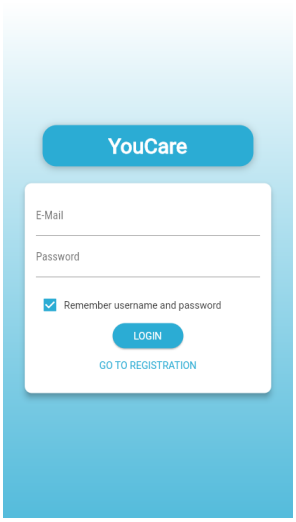
Non-functional requirements include:

- The registration process should be as fast as possible even in cases where the user is subscribing other people.
- The design of the system, especially with regard to the mobile application, must be as intuitive as possible due to the very diverse user base.
- The application must be available for as many devices as possible (both mobile and desktop).
- Access to the data and services offered by the system must meet the most common security standards. No user should be allowed to access the confidential data of other users to which he/she is not entitled. Access to the patient's data should be restricted to their physician.
- The system must be always online.

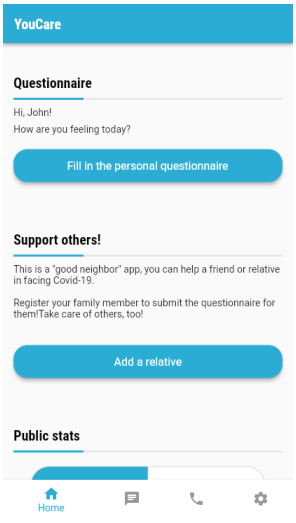
Based on the identified requirements we proceeded with the development of the app. The app development was performed using the Flutter framework, which allowed the development of a cross-platform Android, iOS, and Web application with a single codebase in Dart. As shown in Figure 1a, the user, in order to access the application must register to the platform by entering his personal data. In order to validate his identity, adapting the app to the Italian national health system, the number printed on the Italian health card is requested (a confidential number of which only the regional health authority should be aware; this validation should be adapted to the health systems of the various countries). This same check is used to allow one person to use the app on behalf of another. However, it is always possible for a person to register themselves, in which case they can decide whether to still allow the other person to use the app on their behalf or to remove that ability. Finally, the app's functionality will only be accessible to individuals for whom there is a positive (or scheduled/pending) COVID-19 test in the regional health



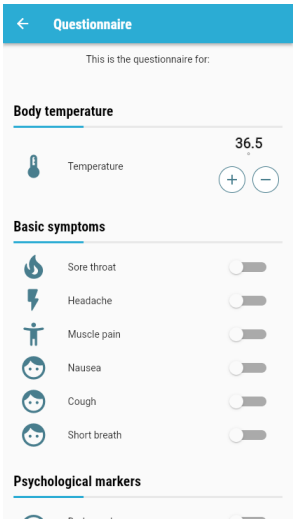
(a) User registration



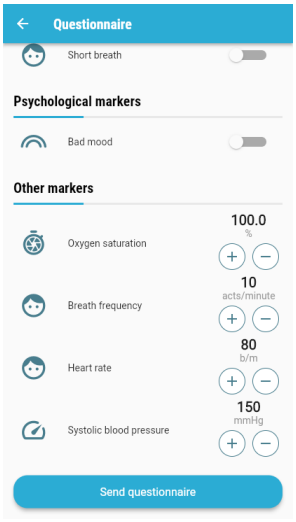
(b) Log in



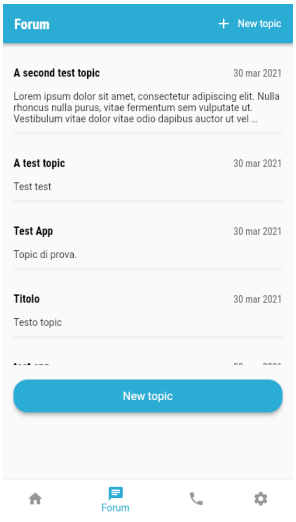
(c) Home screen



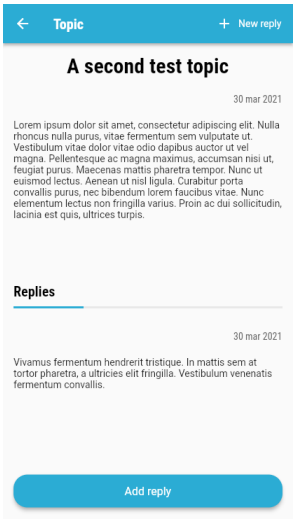
(d) Questionnaire (part 1)



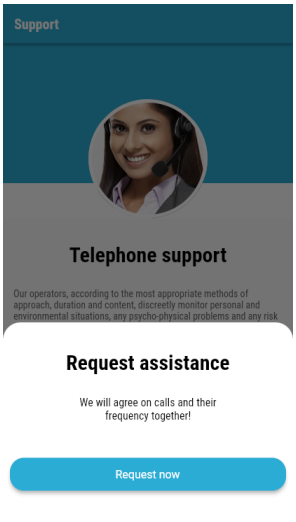
(e) Questionnaire (part 2)



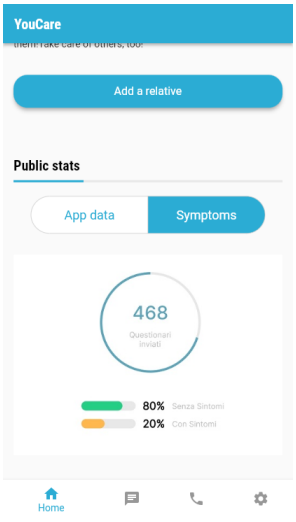
(f) Forum



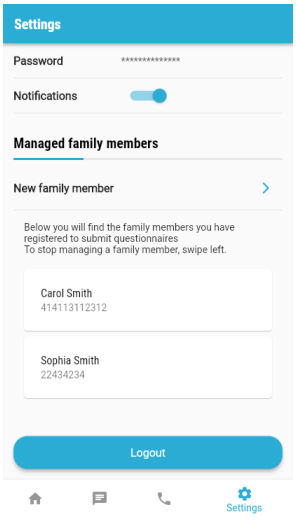
(g) A topic (forum)



(h) Telephone support



(i) Public stats



(j) Settings

Figure 1: Application screenshots.

system (again, this also needs to be adapted to the country's health systems).

After registration, the user can log in (see Figure 1b) and access the home screen of the application (see Figure 1c). From the home screen, the user can access the filling of the questionnaire (see Figure 1d and Figure 1e) that allows the user to enter his medical data daily and forward them to the server, thus allowing their vision to his physician. YouCare also allows the user to fill out questionnaires for other people (for example relatives who do not have a device with Internet access), in fact, the home screen presents a section for handling relatives. It is possible to add a relative by clicking the relative button (see Figure 1c) on the home screen (the number of the health card of the person to be added is required). After that, it is possible to fill in the daily questionnaire with the medical data. At any time, a person added by other users can register as a new user to the platform, thus taking possession of their user. The user, who previ-ously managed the daily questionnaires, is notified of the registration by a notification on the device. YouCare offers features aimed at improving the psychological well-being of quarantined patients. These features include a forum where users can interact with other users (see Figures 1f and 1g), and a "Telephone support" section where users can request a telephone contact from their physicians or a health care professional (see Figure 1h). On the home screen the user can also view some global statistics about the application and the daily questionnaires of the users (see Figure 1i). Together these social and informational functions can be helpful to the person's emotive state. This information could be of moral support since it will show the run-time collective status of people in the same condition. Finally, there is a "Settings" section (see Figure 1j).

The application communicates with a server that provides a JSON API for the functionality needed by the app and takes care of storing the data entered by the users. The server uses PHP and MySQL technologies and uses the JSON WEB TOKEN standard (JWT - RFC 7519 [6] standard) for authentication management. The Google Firebase Cloud Messaging service [13] is also used to manage YouCare push notifications.

A web-based platform, shown in Figure 2, is also available for physicians to view patient data and medical information. The system administrator can add a physician to the system, and the association between a General Practitioner and his patients can be automatically performed thanks to the health card numbers (at least in countries that provide this association, such as Italy). The doctor can view the data entered by each patient through the daily questionnaires and statistics on the questionnaires. A MEWS scale [29] score is also provided for each patient in order to immediately alert the physician of a possible clinical instability of the patient. The score obtained from the scale ranges from a minimum of 0 to a maximum of 14. Above level 5 the patient is criti-cal and unstable. For all other patients with normal values, however, the MEWS is an important tool for early detection of worsening clinical conditions.

Table 1
Tasks performed by the experiment participants.

	Task
1	Register a personal account from the app
2	Log in
3	Look at the public statistics from the app
4	Fill out a questionnaire for themselves
5	Add a first relative/family member
6	Add a second relative/family member
7	Remove one of the two relatives/family members
8	Fill out a questionnaire for a relative/family member
9	Add a new topic to the forum
10	Reply to one of the existing topics
11	Request phone support from the application

4. Evaluation

We carried out a user study aimed at evaluating the usability of YouCare. In the experiment, we asked participants to use the app's features and then evaluate the app by filling out a questionnaire.

4.1. Participants

For the experiment, 23 participants who decided to participate for free were recruited. They were divided into two groups based on age. The 20-29 group consisted of 15 participants (2 women), all college students between 20 and 28 years old ($M = 22.3$, $SD = 2.6$), regular users of computers and smartphones. Two of them had personally dealt with COVID-19. The 55-64 group consisted of 8 participants (2 female) between 55 and 64 years old ($M = 58.1$, $SD = 2.9$), all regular smartphone users.

4.2. Apparatus

The experiment was conducted on the individual participants' smartphones due to restrictions due to COVID-19 that prevented direct contact. All devices are recent Android smartphones from different manufacturers (Samsung, Xiaomi, etc.). The server was running an 8-core server with 32 GB of RAM running Ubuntu 20.04 and with a gigabit internet connection.

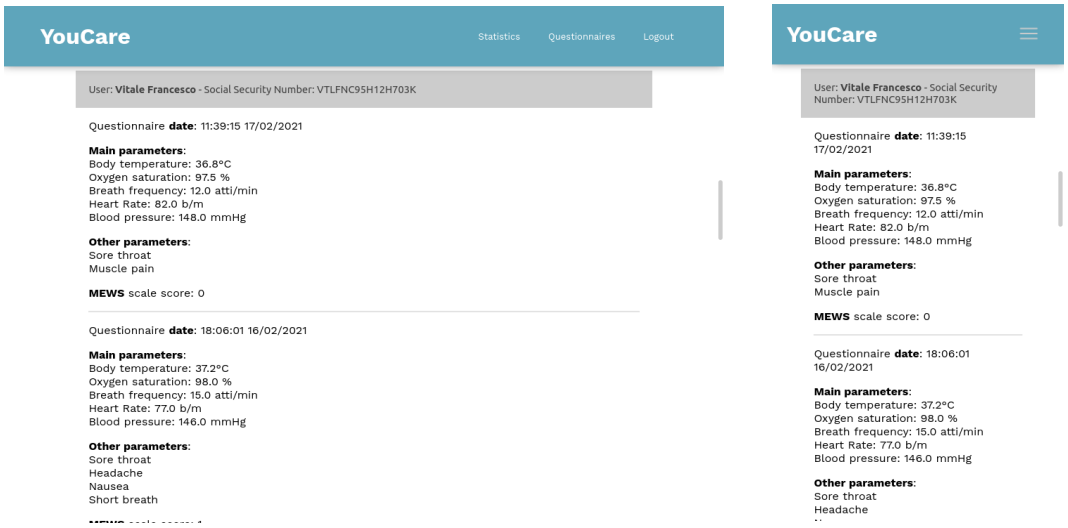
4.3. Procedure

Before starting the experiment, the participants filled out a questionnaire with the following information: personal data (age, gender), previous experiences with smartphones, personal experience with COVID-19.

Participants were asked to use the app, performing a list of the most representative tasks (see Table 1). In order to assess the intuitiveness of the app, no explanations were given about it or on how to perform the tasks.

At the end of the experiment, they were asked to submit a form in which they could write free-form comments, both about the app in general and about the performed tasks.

Moreover, they were asked to complete a System Usability Scale (SUS) [9] questionnaire. SUS includes ten statements (see Table 2), to which respondents had to specify



(a) Desktop view (b) Mobile view

Figure 2: Web-based platform for physicians.

Table 2
SUS questionnaire.

	Question
1	I think that I would like to use this system frequently
2	I found the system unnecessarily complex.
3	I thought the system was easy to use
4	I think that I would need the support of a technical person to be able to use this system
5	I found the various functions in this system were well-integrated
6	I thought there was too much inconsistency in this system
7	I would imagine that most people would learn to use this system very quickly
8	I found the system very cumbersome to use
9	I felt very confident using the system
10	I needed to learn a lot of things before I could get going with this system

their level of agreement using a five-point Likert scale. The questions alternate between positive and negative (since they are in a rather standard form we do not include them here). Each SUS questionnaire has a score between 0 and 100, of which we then calculated the averages on all participants.

Finally, we also collected further feedback through verbal interaction.

5. Results and discussion

All participants completed the experiment. For each participant, the experiment lasted about 20 minutes.

From the server logs, we were able to verify that all participants in both groups successfully completed all tasks.

For the 20-29 group, the average SUS score was 83.3 ($SD = 9.6$), while for the 55-64 group the score was 73.8 ($SD = 11.8$), which are both good values [26].

Regarding free form comments and interviews, for both groups the feedback was generally positive about both the usability of the app and its usefulness. The most common suggestion concerned the ability to view the status (confirmation) of the telephone support request. Other suggestions include adding reminders, integration with smart devices for health monitoring, keeping the name of sections always visible in the UI, adding more information about the general statistics.

Most of the difficulties in using the application were reported by the 55-64 participants, primarily in the interaction required to remove family members. Some participants did not notice at first the navigation buttons at the bottom of the app screen, trying to perform all tasks from within the home screen and thus having difficulty when performing the first task for which their use was needed. A single participant had difficulty performing 4 tasks, finding the interaction mode not intuitive. Finally, a bug that occasionally occurred when adding/removing family members was reported.

The obtained results may be regarded as good, since even if the 55-64 group had more difficulties in carrying out some tasks, all participants managed to successfully complete all tasks. It must be noted, nonetheless, that all participants were regular smartphone users. People with little or no experience with them, or older people, might have more difficulties. However, this is mitigated by the fact that one person can use the app in behalf of another person.

6. Conclusions and further works

In this paper, we presented YouCare, a COVID-19 patient telehealth application whose application design was influenced by the analysis of existing applications and interviews with COVID-19 patients.

Future work includes the possibility of directly interfacing the application with Bluetooth wearable devices in or-

der to allow for the collection of some of the medical data without the need for the user to fill out the questionnaire in an ongoing and more reliable manner. It is also intended to integrate a video call feature to complement the phone contact and allow users to receive COVID-19 test reports and medication prescriptions from their doctor directly from the application.

7. Acknowledgment

This work was partially supported by the grant "*Fondo FSC 2014 2020 per il Piano Stralcio Ricerca ed Innovazione 2015-2017 - MIUR - progetto MEDIA*" (project code: PON03PE_00060_5/12 - D54G14000020005).

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