TITLE: DIGITAL CONTACT TRACING – AN EVALUATION OF THE NHS COVID-19 APPLICATION

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ABSTRACT

The unwavering COVID-19 pandemic has caused the loss of six million lives with million others having suffered catastrophic events. With that being said, this is but the tip of the iceberg as the closure of schools and businesses severely damaged all aspects of society as well as the economy.

Governments worldwide in response have introduced Digital Contact Tracing (DCT) applications, permitting surveillance over individuals whilst everyday life remains unaffected. In accordance with studies conducted, DCT applications rely on the extensive and fruitful consumption by the public, with uptakes rates reaching about 60% of the overall population. Even so, the effectiveness of these applications is unknown due to privacy preserving policies such is the data minimization policy which hinders the extraction of data about the actual usage of DCT applications. [1]

This dissertations aims to assess the effectiveness of DCT applications by conducting an in-depth and iterative evaluation of the NHS COVID-19 application that covers the regions of Whales and England. Encompassed in this evaluation is a thematic analysis of publicly available user reviews to better understand user perspective and needs from such applications, gaining broad insight on any differences between positive and negative sentiments towards DCT applications

DECLARATION

"I proclaim that the following dissertation has been comprised entirely by myself, representing my own work except where otherwise stated by a reference or acknowledgment that the work is not my own."

ACKNOWLEDGEMENTS

I would like to extend my gratitude to my project supervisor Dr Vasilis Vlachokyriakos, for granting me the opportunity to undertake this dissertation topic, as well as professionally supporting me throughout the entirety of the dissertation process.

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DISSERTATION STRUCTURE AND CONTENT

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Section C – What Was Done And How: A step-by-step process covering what has been achieved in the project, and how.

Section D – Results And Evaluation: Showcase of the end product of the project and an evaluation of the findings discovered and results of the project.

Section E – Conclusions: An overview assessing the entirety of the project, measuring the aims and objectives against the product developed, and any future work.

SECTION A – INTRODUCTION

BRIEF SUMMARY

With societies all around the world pushing the restart button to reclaim their lives, the unwavering Covid 19 pandemic continues posing an issue. In response, several governments have imposed a series of measures to combat the pandemic, including Digital Contact Tracing (DCT) apps that surveil individuals whilst permitting life to carry on. DCT apps replace the laborious manual process of recalling all recent contacts and activities of an infected individual, surpassing it in terms of scale and speed.

Despite DCT apps being ground-breaking tools in the pandemic scene, to reach full effectiveness, the extensive, fruitful and broad consumption by the public is necessary. Privacy preserving policies however hinder the evaluation of the effectiveness of DCT apps, by preventing the extraction of meaningful data about the actual usage of these apps. Subsequently, identifying the uncertainty and doubts clouding DCT apps ignited the ambition to undertake the evaluation of the NHS Covid 19 app that covers the regions of England and Wales. This ambition lies in the hopes that the outcome results could contribute towards an increased uptake of DCT apps by the world.

PROJECT PROPOSAL CHANGES

Originally stated in the project proposal for this project that a low-fidelity prototype or wireframe was considered to be developed incorporating an innovative design for the NHS COVID-19 application. During the carrying out of the prototyping phase, it was immediately identified that a side-by-side development with the actual application would enable the swift transferring of key design elements with minimum effort on the researcher's end. Thus, the objective in agreement with the supervisor of this project, to be changed from considering a low-fidelity prototype but rather a high-fidelity prototype instead.

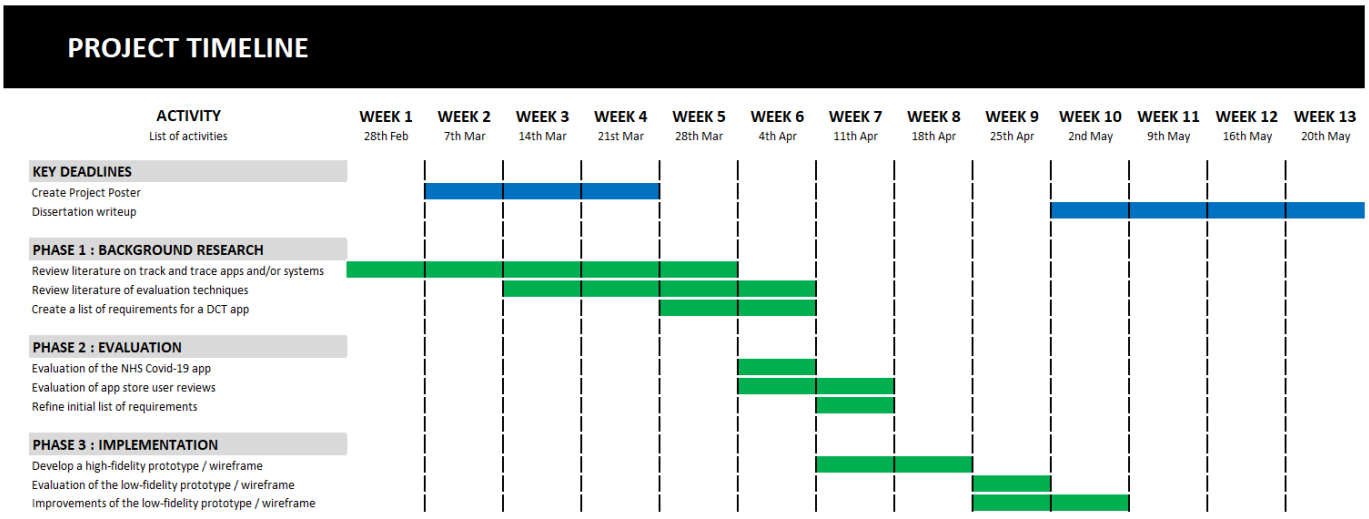


Figure A1 – Final iteration of the project plan

The initial project plan too suffered some modifications, with the most significant being the addition of one week to the schedule due to some personal circumstances. The above figure encapsulates that as well as any minor alterations to the day-to-day schedule.

AIM AND OBJECTIVES

Aim: The overall accomplishment aimed to be achieved is the in-depth and iterative evaluation of the NHS COVID-19 application, and based on findings develop an alternative optimized design in terms of user experience (UX) and user interface (UI).

Objective #1: Review literature on track and trace applications and systems to produce a list of requirements

The development of an effective and user-centred track and trace application necessitates the assembling of a set of functional and non-functional requirements. This list will be derived by reading and exploring other applications and systems that exist within this space, providing a foundation for what technologies and features are housed and desired by these tools.

Objective #2: Review literature on evaluation techniques and select suitable methods to be carried out

There will be two main evaluations involving the NHS COVID-19 application in objective 3, and a high-fidelity prototype in objective 4. Numerous evaluation techniques will be investigated from research papers that incorporate user content for user-centred design, and compared to identify appropriate evaluation techniques for the attainment of highest valuable findings.

Objective #3: Evaluate the NHS COVID-19 application to produce an iterated list of requirements

Upon familiarisation with the NHS COVID-19 application, an appropriate evaluation technique selected in objective 2 will be employed to evaluate the application and uncover any prevailing issues. Likewise, an analysis will be carried out on the user reviews of the application, obtained from the Google Play Store and Apple Store. Findings from the overall evaluation phase will support the iteration of the initial list of requirements identified in objective 1 with a set of innovative design goals and requirements that will be made usage for the re-design of the NHS COVID-19 application.

Objective #4: Develop a high-fidelity prototype or wireframe based on the requirements list

The iterated list of requirements produced in objective 3 will shape form a new design for the NHS COVID-19 application, that will be developed into a high-fidelity prototype or wireframe. As previously familiarised with in related HCI modules, commonly accessible prototyping tools such that is Adobe Xd and Balsamiq will be used.

Objective #5: Evaluate the high-fidelity prototype or wireframe to polish the prototype

Accomplishment of the new design in objective 4 and with the assistance of an evaluation technique selected in objective 2, the high-fidelity prototype or wireframe will undergo an evaluation to discover any issues compelling alteration of this new design as well as any other remarkable insights.

CHAPTER B – TECHNICAL BACKGROUND

DIGITAL CONTACT TRACING

Digital Contact Tracing (DCT) is the automation of the conventional process of contact tracing that involves the uncovering of contacts by manually retracing an individual's recent movements and interactions when medically diagnosed with COVID-19. With the assistance of primarily smartphone-based proximity tracing applications, individuals that have come into close-proximity contact with potentially infectious individuals are immediately identified.

CENTRALISATION AND DIGITAL CONTACT TRACING

In common, DCT applications generate, store and process a sequence of random temporary identifiers (IDs) on the user's device, that can be transmitted to the device of another individual and a central server that is operated by public health authorities. Handling of these IDs can be approached through a centralised or decentralised process, in respect with the communication protocols employed.

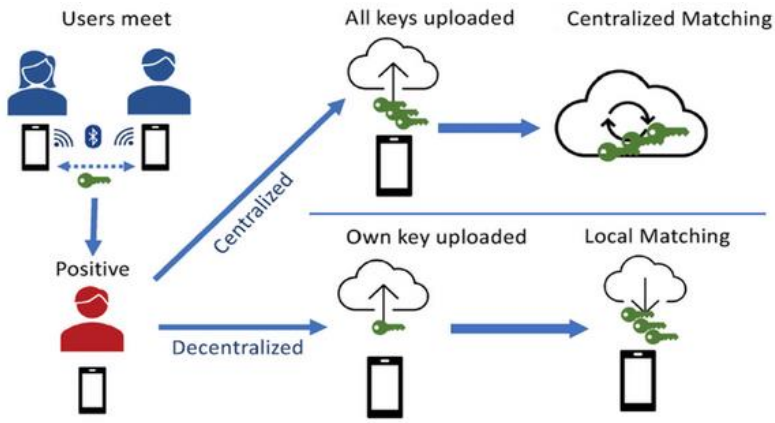


FIGURE B1 – Centralised vs Decentralised approach [21]

When an individuals is diagnosed with COVID-19 or is considered as a potentially infectious individual, and decides to upload that data to the central server, a centralised approach will permit immediate access of all recent IDs to the server whereas a decentralised approach will solely permit access to the IDs of the infected individuals. Therefore, when performing matchmaking of individuals with contacts, a centralised approach manages IDs on the user's device whilst a decentralised approach achieves this on the central server. [19]

In essence, the two approaches are distinguished by the sole factor concerning the extend of the personal information that public health authorities are authorized access to. [20]

DCT TRACKING APPROACHES

Existing DCT applications have approached the matter of surveillance in different manners, with some making usage of a combinations of features.

Approach #1: Bluetooth Low Energy (BLE) enterprise tag – Designed for a controlled workplace, the Bluetooth Low Energy (BLE) enterprise tag approach enables continuous tracking operations within range of areas assigned for the workplace by overseeing a set of rules and their compliance by the employees.

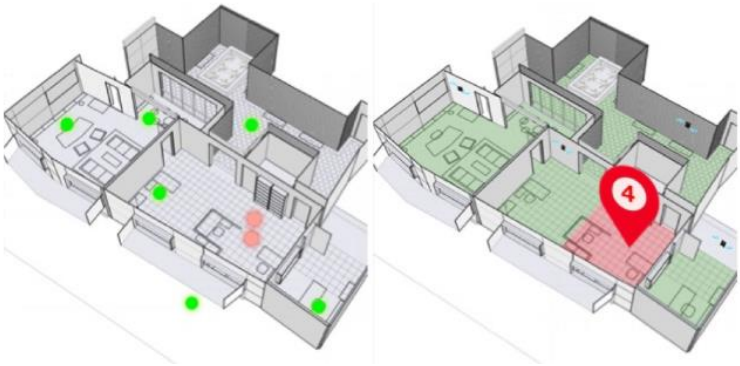


FIGURE B2 – BLE enterprise tag approach

This is done by initially placing a BLE tag on an employee's ID or any other convenient mean, which is then read by central controllers known as IoT hubs located around various key positions of a building or site. A BLE tag establishes communication with a secured and anonymous database through these hubs, updating information in real-time as an employee moves around the workplace. Based on a set of context-based rules, the database in return checks location information to verify if an employee is rightfully at a matched location as well as if there has been a breach in the number of individuals permitted at the matched location. [2] Supporting technology known as iBeacon devices or beacon devices, collect and transmit Bluetooth-proximity data to an application installed on a receiving device, which determines the physical location of an employee. These applications could then alarm the employee when in-close contact with potentially infectious individuals in addition to administering a set of rules. [3]

Approach #2: Bluetooth & Global Positioning System (GPS) approach – Bluetooth and Global Positioning System (GPS) technologies are ultimately used to trace down an individual's movements and detect any contact with potentially infectious individuals. Both technological approaches accomplish this by establishing communication between smartphone devices, that have a common DCT applications installed, when individuals cross paths. Bluetooth technology measures the level of exposure by the duration, frequency and transmission strength of Bluetooth signals exchanged between devices whilst GPS technology measures this solely by the duration of contact using geographic location of the individuals.[4] When the threat of exposure to an infectious individual is high enough, individuals are immediately notified to follow the necessary guidance, limiting the spread of the virus. Some DCT applications use a joint approach of these technologies to improve the accuracy in identifying exposure by maintaining continuous tracking of an individual's location. [3]

Approach #3: Symptom tracking approach – Unlike other surveillance approaches that rely on the level of exposure to some degree, the symptom tracking approach solely pulls together symptom information by individuals on a daily basis and assesses the possibility of an individual being infected by COVID-19. Tracking of symptom information is conducted through the day-to-day self-reporting of symptoms by individuals, or even data collected from monitoring an individual's resting heartbeat. Some DCT applications incorporate the linking of medical records to further improve the assessment process. [4] Merging the use of zip codes with symptom information permits the forecasting of regional outbreaks of COVID-19, leading to appropriate adjustment of restrictions imposed on individuals. [4]

DCT APPLICATION FEATURES

Risk Score System – A feature that encompasses automated decision making by developing a risk score system that essentially calculates the likelihood of an individual being infected by COVID-19. This could be achieved by relying on the engage and willingness of an individual to self-report any symptoms experienced, by reporting any tests conducted and by collaborating with a surveillance feature assessing the length of exposure to potentially infectious individuals. [5]

Guidance – Most commonly, the majority of DCT applications incorporate guidance through the use of suggestions on the type of actions to undertake in limiting the spread of COVID-19, instructing individuals on matters such that is self-isolation, social distancing, resources for nearby COVID-19 testing sites, and so on. [3] Guidance can further manifest in the form of Telehealth, health-related services over technological communications, or even through educational means including provision of local news and the up-to-date governmental protocol**.** [6]

CHALLENGES WITH TRACK AND TRACE APPROACHES

The challenge encountered by the majority of DCT applications and systems is the trade-off between effectiveness and public acceptance. Decisions made require cost-benefit judgments, where the benefit of implementing a certain option must be greater than the cost.

Incentivisation – Despite the World Health Organization (WHO) pushing for completely voluntary DCT applications and systems, a challenge posed by such a system is that without the implementations of any incentives to download or use the apps, a long-standing engage by the population seems very unlikely. [8] In an experiment conducted on Germany's DCT application known as Corona-Warn, exhibits the randomized offering of small monetary incentive to non-user individuals upon installation of the app, resulting in a significant increase in uptake. [7]

Practicality – Effectiveness of a DCT application predominantly relies on heavy user-app interaction, necessitating a series of conditions to be met. For the majority of tracking approaches, individuals are expected carry a suitable device on the person at all times whilst having the corresponding DCT application downloaded by not only themselves but also every other individual that they cross paths with. Thus even if the public embraces DCT applications, many individuals and especially older individuals who are not technologically up-to date, may never grasp onto the opportunity to make usage of these applications. Yet even when all participants have the app downloaded, full functionally for approaches that involve technologies such that is Bluetooth or GPS, individuals are required to furthermore activate their operation within the applications. [4]

Reliability – DCT applications in common deal with the inevitable issue of inaccuracies materializing, resulting to the provision of incorrect guidance at times. Inaccuracies can manifest within buildings or other indoor settings where surveillance relying on proximity or location can be hindered by multiple layers of protection or poor connectivity to Wi-Fi or cell signal. [4] The setting the individual is located is of great

significance as both enclosed and open spaces can impede the evaluation of an individual's exposure to others. Yet even when the technology itself does not produce any inaccuracies directly, DCT applications have limited capabilities when it comes to the identification of short instances or events, such that is a cough or a sneeze. [3]

Privacy concerns – Irrespective of how securely and anonymized data collection is conducted by DCT applications, individuals will raise their concerns about the invasion of their privacy. [2] Concerns relating to how much personal information is being withheld with or without their consent, and who has the right to use to such confidential information. Anonymization of information can be rather difficult with certain technologies such that is GPS, which could possibly lead to their undesirable extraction and exploitation by unwelcomed individuals. [3]

EVALUATION TECHNIQUES FOR ANALYSING USER REVIEWS

For the analysis of user reviews, a series of research papers have been reviewed, each employing a unique technique to the handling of different types of data.

SYSTEMATIC REVIEW APPROACH

A study was conducted in 2020 [9] on the utilization of mobile health applications that complement standardised methods of treatments for patients suffering from PTSD. This was due to several concerns being brought to attention about the overall effectiveness of these applications and the potential harm inflicted towards these individuals.

The investigation was driven by an evaluation of relevant existing PTSD applications in terms of the content and quality offered by each. Two independent reviewers collected and evaluated these applications using the German version of the Mobile App Rating Scale (MARS-G). The quality evaluation focused on engagement, functionality, aesthetics and information quality, whilst the content evaluation focused on therapeutic gain, subjective quality and perceived impact.

	App quality rating				Additional subscales		
ore	Engagement	Functionality	Aesthetics	Information Quality	Therapeutic Gain	Subjective Quality	Perceived Impact
	4.60	4.88	4.67	4.67	4.33	4.19	4.13
	4.60	4.75	4.50	4.67	3.96	4.13	4.42
	4.60	5.00	4.67	4.17	2.00	4.00	2.00

Figure B3 – Means of the MARS-G ratings in descending order of the total mean score

A snipper of a table envisioned in the above figure showcases the total mean scores of the different evaluation items previously discussed, calculated using the ratings from the reviewers.

SENTIMENT ANALYSIS APPROACH

A study was conducted in 2011 [10] on the sentiment expressed by views and opinions on microblogging websites such that is Twitter. Analysis of sentiment however can be a challenge, especially when determining whether or not the overall sentiment is positive, negative, or neutral.

For the study, a sample of about 12000 manually annotated tweets was acquired, where each tweet was then manually labelled as positive, negative, neutral or junk. Before processing the data, two dictionaries were developed :

- an emoticon dictionary labelling emoticons with a corresponding emotional state
- an acronym dictionary consisting of translations for each acronym

Acronym	English expansion
gr8, gr8t	great
lol	laughing out loud
rotf	rolling on the floor
bff	best friend forever

Figure B4 – Acronym dictionary

The data was then thoroughly processed by substituting emoticons with the emotional state as labelled in the emoticon dictionary, removing repeated characters, as well as replacing URLs, targets and negations with appropriate tags. Doing so permitted the assignment of a pleasantness score to each individual word, contributing to a polarity score by an overall piece of text. This was achieved using the DAL dictionary extended with WordNet, a vocabulary database of semantic associations between words.

THEMATIC ANALYSIS APPROACH

A study was conducted in 2019 [11] on the utilization of user reviews to uncover any matters encountered or potential improvements desired by users, to support the enhancement of app usability and user experience of an application. This is exceptionally of essence when handling sensitive areas such that is mental health.

In this research, a sample of about 1200 user reviews was extracted using the Heedzy tool and analysed from a range of related mental health apps. The user reviews were then manually coded, with emphasis on negative reviews relating to usability issues, resulting in the development of six categories as follows : bugs, poor user interface design, data loss, battery and memory usage issue, lack of guidance and explanation, internet connectivity issue. After sorting out the user reviews, a list of all usability issues and a list of all UI design issues were generated, paired with a description and a user review example.

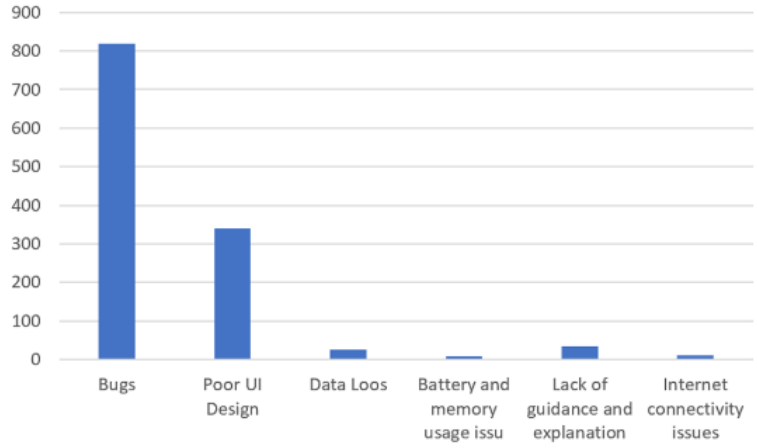


Figure B5 – Usability issues of mental health apps

Another study that was conducted in 2016 [12] on the usage of parental control applications, instead compares themes between top-rated reviews and low-rated

Rating	Words	Themes
<=3	worth, useless, app	useless
	can't, lock, playstore, device, not, easy, age, settings	problems in age-appropriate settings
	uninstalled, refuses, prevention	uninstallation problems
>=4	block, protect, limit, control, websites, porn, everything, free	block restricted content
	useful, great, works, properly, clean, user, friendly, excellent	user-friendly app
	safe, protect, children, family	protects family

Figure B6 – Thematic analysis of user reviews of Safekiddo app

reviews, as well as top-rated applications and low-rated applications. High-rated was considered a review of 4 or more starts whilst any review below that was a low-rated review.

This can envisioned in the figure concerning an empirical user study of an application called "Safekiddo Parental Control", paired up with relevant key words assigned to each theme.

USER-GENERATED CONTENT APPROACH

A study was conducted in 2013 [13] on the contents of the interactions shared by men and women on Facebook, and the potential differences in the variety of topics discussed and the feedback received by the respective audiences. Text-based interactions such that is status updates that are directed towards larger audiences who can interact through comments and likes, would enable the uncovering of these unknown interactions.

The research involved the acquiring of one million status updates and the applying the Latent Dirichlet Allocation (LDA) method fort the identification of common or rather hidden topics, by clustering words that frequently co-occur.

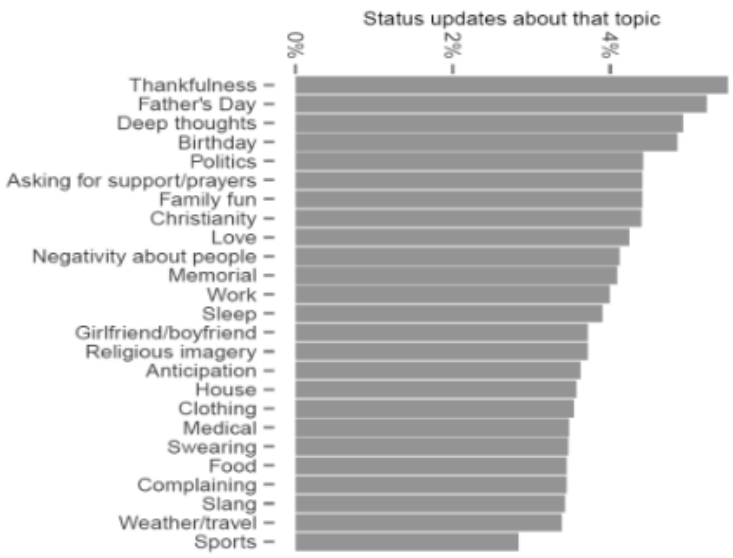


Figure B7 – Status update for each topic

LDA topics models were constructed from the data and utilized in the generation of a dictionary, pairing each individual topic with a sequence of related vocabulary. Status updates were then defined when three single or consecutive word sequences could be matched from the corresponding topic's dictionary. The responsiveness aroused by each topic can be visualised in the figure.

EVALUATION TECHNIQUES FOR USABILITY TESTING

Intended for the evaluation of the NHS COVID-19 application and the high-fidelity prototype, by utilizing knowledge acquired from previous HCI related modules in the course, a variety of well-known evaluation techniques have been further explored to assess their suitability for this study.

COGNITIVE WALKTHROUGH APPROACH

Cognitive walkthrough is a task-specific approach that evaluates the usability of an application, and in particular the ease with which tasks can be carried out by a new user. This involves the breaking down of a specific task into a series of tasks, and presented in either a list structure or a diagram if the accomplishment of a task is deemed too complicated for the user to grasp and follow through. Whilst the user is carrying out each process, four questions are being posed to which the user responds in accordance with the satisfaction level experienced. These questions are as follow :

The right effect –	Will the user attempt to accomplish the correct outcome and will it correspond to the user's end goal?
Visibility –	Will the user identify that the corresponding action is available in the first place?
The right meaning –	Will the user comprehend that this is the desirable action upon visibility?
The right outcome –	Will the user comprehend that progress is achieved upon taking the action?

In parallel the researcher ensures to record each step, along with any successes, failures, design suggestions, issues, assumptions and general comments raised by the user. Findings from multiple users are then summarised and prioritisation is set on any issues identified to be resolved.

Due to the ability to conduct a cognitive walkthrough with ease and swiftness, feedback responses are generated at an equivalent speed. Therewithal, the feedback received by this approach permits the researcher to envision the evaluation from a user's point of a view instead of an expert's. [14]

HEURISTIC EVALUATION APPROACH

Heuristic evaluation is a trial-and-error approach that evaluates the usability of user interfaces, by assessing principles that have been proven to be effective and reliable, against certain elements of a user interface. This involves the defining of a set of established heuristics to be used by experts when measuring the usability of a user interface, resulting the in the reporting of any issues encountered. The evaluation can be split into several walkthroughs, with evaluators conducting an evaluation following rigorously the heuristics provided or by making usage of the product without any constraints. Findings from the experts will allow the uncovering of any issues or perhaps produce solutions with the assistance as a result of suggestions provided by the evaluators.
To reach although the fruition of such results, the researcher should ensure that the correct heuristics are chosen to enable the uncovering of the entirety of existing usability issues. Not only that, but the researcher should seek for relevance of the issues raised since not all issues may concern usability, whilst the ones that do should be taken with a grain of salt as the may lack the necessary evidence or even be biased. It is moreover essential to mention that the evaluators are needed to be actual experts on the topic of usability, consequently conducting such an evaluation becomes more difficult and expensive. [15]

THINKING ALOUD APPROACH

Thinking aloud is an eavesdropping approach that requests from participants to express verbally whilst making usage of a product, what they are visualising, thinking, conducting or experiencing as they navigate throughout its user interface. The researcher merely provides a series of tasks to be carried out by the users and ensures to record notable interactions along the way leading to the uncovering of what the users essentially feel about the design of the system. [16]

Undeniably, this approach is relatively straightforward to carry out, and unless data extraction is biased in any manner, findings are guaranteed. Yet for a proper evaluation to be conducted, the researcher should ensure that participants properly engage and interact throughout the evaluation, as an extensive monologue can be exhausting for some. Another point of emphasis is ensuring that the engagement of the participants gets delivered unprocessed and unfiltered, as some individuals tend to hesitate before speaking. [17]

CHAPTER C – WHAT WAS DONE, AND HOW

STEP 1: CONSTRUCT LIST OF REQUIREMENTS

Upon concluding the research phase of the project, entailing the reviewing of relevant literature of track and trace applications in the space as well as the exploration of a variety of evaluation techniques, the first and foremost step is the development of a list of DCT desirable functional and non-functional requirements.

BEST TRACKING APPROACH

	Incentivisation	Practicality	Reliability	Privacy
BLE enterprise tag			✓	
GPS / Bluetooth				
Symptom tracking		✓	✓	✓

The existing DCT tracking approaches are cheap, simple with minimum maintenance, nevertheless offer a trade-off between incentivisation, practicality, reliability and privacy. For an effective DCT application, the highest possible adoption rate by the public is desired meaning that the voices or rather concerns of individuals would be valued much more than the provision of a tracking approach that performs outstandingly. With that being said, this logic primarily stands when DCT applications are not enforced upon the public and are completely voluntary, even in job settings referring to the BLE enterprise tag approach.

As can be observed in the above figure, the symptom tracking approach clears most criteria concerning this, the GPS/Bluetooth approach has one too many loopholes deeming it unable to clear any criteria, whilst the BLE enterprise tag approach offers a level of reliability over the GPS/Bluetooth approach. Undeniably, the symptom tracking approach can be said to be the most optimal approach under these considerations.

LIST OF INITIAL REQUIREMENTS

In accordance with the literature reviewed at this stage and additional consultation of requirements set out for track and trace applications, by the World Health Organisation (WHO), the following functional requirements (FR) and non-functional requirements (NFR) have been produced. Remark that this list of requirements will undergo iteration at later stages of this study. [8]

REQ ID	NAME	DESCRIPTION	PRIORITY
FR1	Report symptoms	Users must be able to report any symptoms experienced at the present time	High
FR2	Risk score system	The application should inform the user of the likelihood of getting infected by COVID-19	Medium

FR3	Guidance provision	The application should provide a broad variety of information including news, suggestions, instructions, etc.	High
FR4	Language selection	The application should be available in all languages and be accessible to individuals with disabilities	Low
FR5	Medical records	Users should be able to link and manage NHS medical records through the application	Medium
FR6	Data deletion	Application should permit user to delete data at any instance	High
FR7	Postcode login	The application should request upon registration the user's postcode district.	High
NFR1	Voluntary system	Downloading and using the application should be completely voluntary. The user should also be in control of turning off or deletion of the application and/or the data	High
NFR2	Notification privacy	Contacts reported to the user as potentially infectious individuals should have their privacy preserved	High

STEP 2: SELECTION OF EVALUATION TECHNIQUES

EVALUATION TECHNIQUE FOR USER REVIEW ANALYSIS

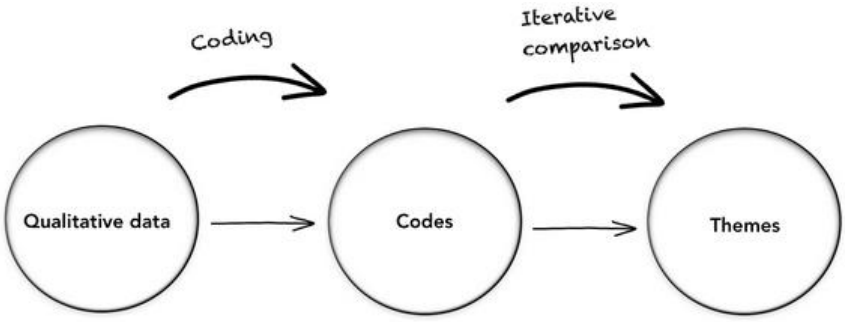


FIGURE C1 – Thematic analysis process [18]

The approaches previously explored all offer great depth when it comes to the analysis of different content, and especially qualitative data. For this research though, a hands-on approach or in other words a thematic analysis, seems to be an optimal approach as the researcher grasps onto the opportunity to comprehend the thoughts, beliefs and requests of individuals to a deeper extend. Rather than emphasising on the implication of words, overseeing the broader image, this approach permits the interpretation of data on what the data is actually about.

A thematic analysis fundamentally involves completely reading all data, coding the data in accordance with the content, and identifying any patterns in the codes created to develop themes. The process of coding can be carried out using software, affinity diagramming techniques or in our case, journaling, which incorporates the hands-on approach by implementing the thought process and ideas of the researcher, through the manual interpretation of data. Undertaking this method permits the researcher to bypass the challenge posed by the variation of the contents user reviews can incorporate, meaning the containment of positive, negative and neutral feedback altogether.

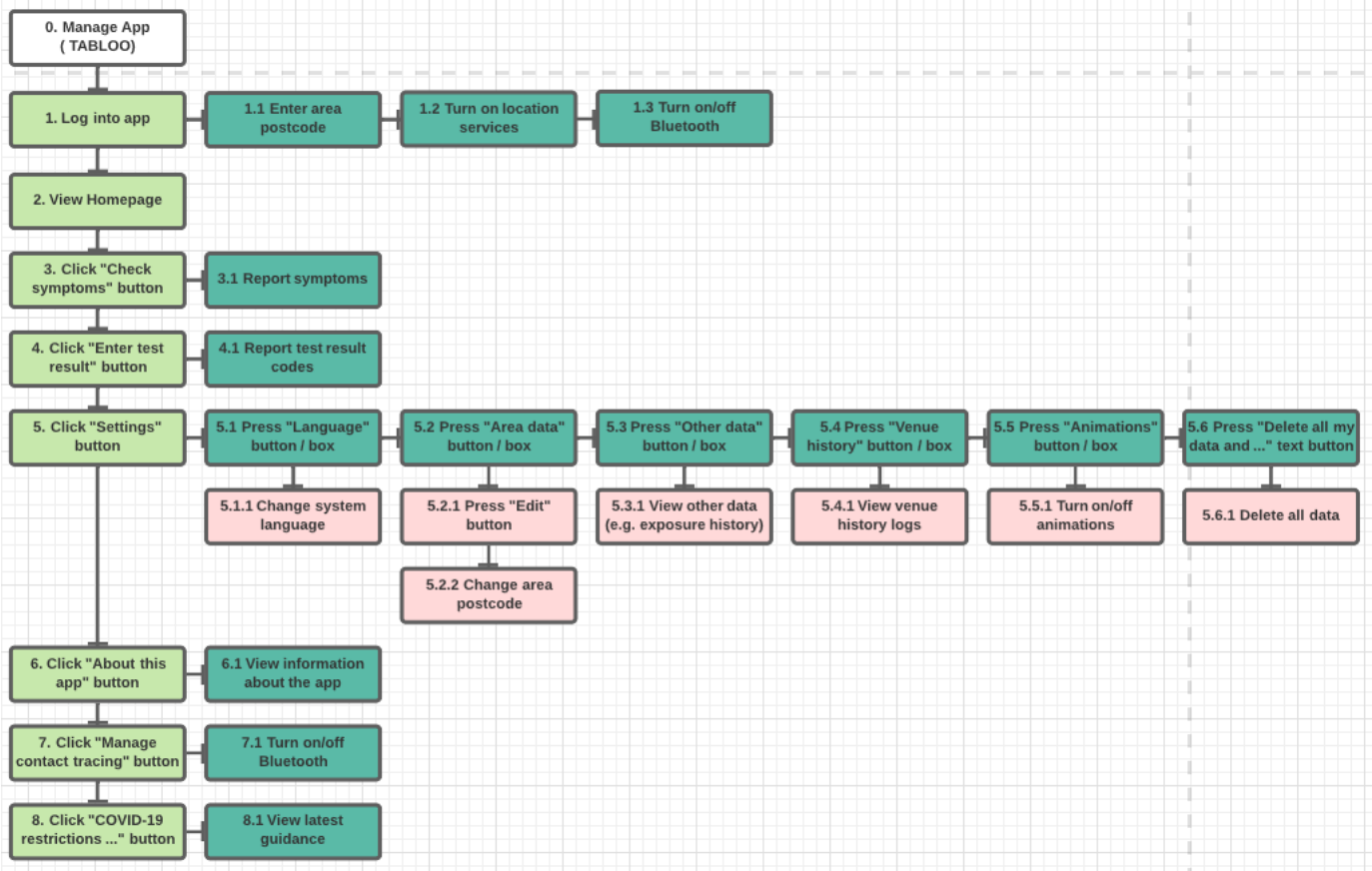
EVALUATION TECHNIQUE FOR PROTOTYPES

Bearing in mind the evaluation approaches discussed, a heuristic evaluation is deemed most appropriate to conduct for the evaluation of the NHS COVID-19 application as the analysis results support an early-stage identification and highlighting of predominantly potential issues relating to usability. Through the use of heuristics, judgements affected by bias and inaccuracies are omitted, simplifying the process of decision-making and effectively speeding up the evaluation phase. Sole amendment to the evaluation is the requirement of the researcher's participation since an expert recruitment would be rather difficult to undertake, whilst limited time constraints in an early phase could lead to the extraction of unpredictable results.

Alternatively, for the evaluation of the high-fidelity prototype, a cognitive walkthrough is deemed best amongst the approaches since it incorporates the conducting of the evaluation by individuals considered as inexperienced users that have no previous experiences with the product or the NHS COVID-19 application. This approach is designed to identify how easily can inexperienced users carry out tasks and learn a product, through a step-by-step structured exploration of an interface. In parallel to this approach, the thinking aloud approach could be employed in the assistance of recording any helpful comments.

STEP 3: APP FAMILIARISATION

To proceed with the evaluation of the COVID-19 application, the application structure was mapped out to ensure complete comprehension of vital functionalities and features offered. The process was conducted in the 6th week of the project, for the 4.27 version of the application which was last updated on app stores on the 29th of March 2022. Consequently, the same version was to be used throughout the project to avoid confusion with potentially new versions coming out.



PLAN

Can do Task 2 by doing Task 1

Can do Tasks 3-8 independently in any order if Task 2 is reached

Tasks 3.1, 4.1, 5.1.1, 5.2.2, 5.3.1, 5.4.1, 5.5.1, 5.6.1, 6.1, 7.1 and 8.1 involve high level objectives

Created using lucidchart. Available: https://lucid.app/

FIGURE C2 – NHS COVID-19 APPLICATION BLUEPRINTS

The application was operated in its entirety, screen recording each interaction encountered and detailing the pathing followed. Documentation supported the derive of a blueprints diagram, envisioned in the above figure, which can be associated with a Hierarchical Task Analysis (HTA) diagram, outlining high-level operations and the necessary steps to be taken to reach them in the application.

STEP 4 (PART I): EVALUATION OF THE NHS COVID-19 APP

CONSTRUCTING A PERSONA

A persona is the representation of potential types of users that may engage with the NHS COVID-19 application as well as the prototype produced by this study. Personas can be powerful design tools when it comes to assisting a researcher in the comprehension of the needs, experiences, behaviours and goals of users. As thus Robert was born, a person that derived from the literature, encompassing the exaggerated characteristics of individuals to look out for when making design decisions.

Robert 35, Male

Created using Random Face Generator. Available: https://this-person-does-not-exist.com/en

- Robert is an employed individual that lives with his parents and fiancé in Waverly, a rural area in the UK
- Did not graduate from high school and is greatly dependent on his fiancé
- Likes to often hang out with his friends at the pub, and does not travel much unless necessary
- Rarely makes usage of technology and even then, only with family members
- No one in the family including Robert have any previous medical preconditions
- In regard to the COVID-19 pandemic, Robert is utterly sceptical and raises his concerns (for matters such that is data privacy) about the national government, healthcare system, and overall science
- Robert has not previously utilized a relevant DCT application

[7]

NIELSEN'S HEURISTIC EVALUATION

Accomplishing crucial preparations concerning in-depth knowledge on the current version of the NHS COVID-19 application, and in correspondence with the selection of an appropriate evaluation technique, a heuristic evaluation was employed for the evaluation of the application. The particular technique makes usage of broad rules of thumb known as heuristics, and since the research for this project focuses on the identification of usability issues identified within a user interface design, Nielsen's heuristic evaluation principals have been employed due to the capability to uncover said usability issues. [22] For the evaluation, 10 usability heuristics have been taken into consideration and utilized as followed:

Heuristic #1: Visibility of system status – The application should ensure that users are kept informed of what is happening, through appropriate feedback within a reasonable amount of time.

Heuristic #2: User control and freedom – Users should be permitted to recover from mistakes by providing a clear emergency exit to avoid any undesirable actions without having to undergo an extensive process.

Heuristic #3: Help and documentation – Opposed to using a system without documentation, it may be necessary to provide additional documentation and support wherever necessary for the user to user to successfully complete tasks.

Heuristic #4: Consistency and standards – A system should attempt to keep all recurring elements similar to prevent confusion as to their implication.

Heuristic #5: Match between system and the real world – Instead of using system-oriented terms, the system should be capable of speaking the language of users with words, phrases and concepts familiar to them. Real-world conventions should be followed, in order to display information in a natural and logical order.

Heuristic #6: Flexibility and efficiency of use – A system can incorporate accelerators which are hidden from novice users and function as shortcut interactions for expert users, essentially catering for both experienced and inexperienced users. Thus, users can be permitted to tailor frequent actions.

Heuristic #7: Aesthetic and minimalist design – A good user interface should not contain a cluster of information, information without purpose nor information that is irrelevant or rarely ever used. This is because supplementary components can reduce the relative prominence and of relevant components of information.

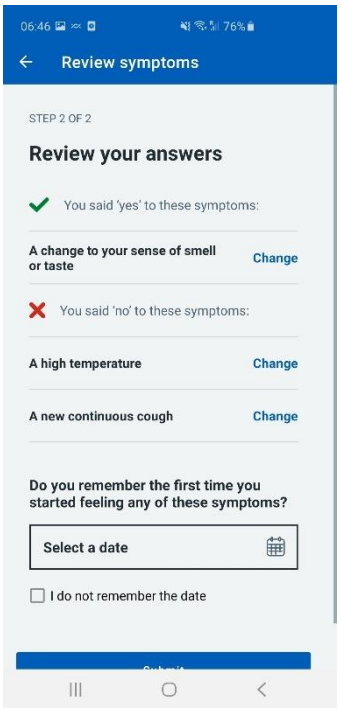
Heuristic #8: Error prevention – As important good error messages can be, prevention of a problem from originally occurring is better. Conditions susceptible to errors should be eliminated or checked through a confirmation option presented to a user before committing to the carrying out of an action.

Heuristic #9: Recognition rather than recall – Information presented in an interface should be kept to the minimum, so the user is not compelled to remember information when traversing a system. The user's memory load can be reduced by making objects, actions and options visible whilst information necessary for use of the system should be visible or easily retrievable.

Heuristic #10: Help users recognize, diagnose, and recover from errors – Plain language with no error codes should be used to express error messages, indicating the problem at hand and constructively recommend a suitable solution.

USABILITY ISSUES OF COVID-19 APPLICATION

Likewise to the documentation conducted for the NHS COVID-19 application and bearing in mind the aforementioned heuristics drawn from Nielsen's heuristic list, the NHS COVID-19 application underwent a heuristic evaluation. Critical issues and discoveries encountered whilst operation of the operation, were recorded beneath the corresponding heuristic along with suitable recommendations for tackling a particular issue. Remark that while all heuristics have been taken into deep consideration, this was not the case for some heuristics as no findings of essence have been identified.

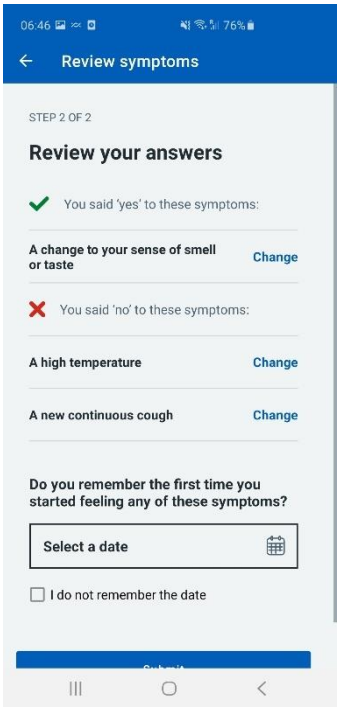


Heuristic #1: Visibility of system status

General findings: The application is for the most part properly labelled with header titles for the user to identify the position currently located at.

Negative Findings & Recommendations

Issue A: In the symptom reporting process, the last step concerning the review of the responses provided by the user in the previous step, can be misleading due to the inclusion of an additional field requesting the selection of the date the symptoms have manifested.



Heuristic #2: User control and freedom

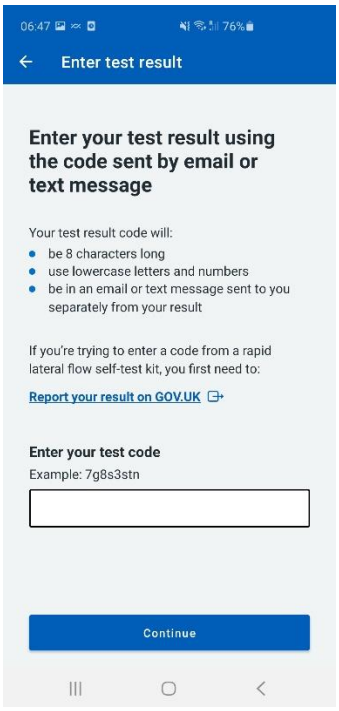
General findings: The applications permits the user to traverse between pages with no restrictions.

Negative Findings & Recommendations

Issue A: When the user successfully reports any symptoms experienced on the day, no option is available to undo this action whilst the symptom report feature vanishes from the homepage after execution of this action. Resolving this issue could be achieved by permitting the user to delete the symptoms recorded, in addition to allowing further reporting of symptoms in case any symptoms have been omitted from inclusion in the first badge.

Issue B: Likewise to issue A, when registering a COVID-19 test result in the application, the user cannot reverse this action. A similar deletion option should be provided to the user.

Issue C: Despite permitting the user to review and modify the responses entered in the first step of the symptom reporting process, the date selection field cannot be reviewed or accessed at a later stage once pressing the submit button. It would be ideal to reshape this process by implementing an additional step before the last step, where the date selection field will be relocated.

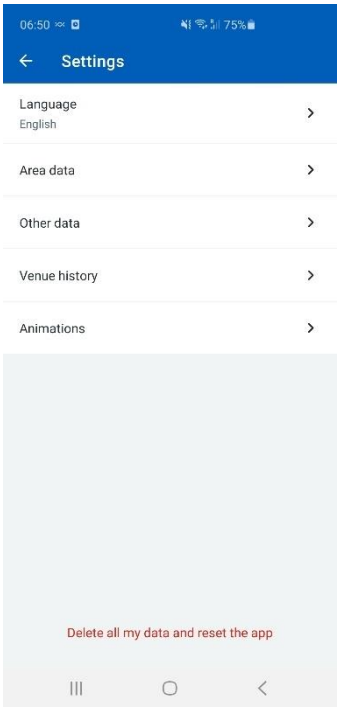


Heuristic #3: Help and documentation

General findings: Documentation is provided about general information of the application whilst every page of the application properly informs the user with context and guidance to completing a particular task.

Negative Findings & Recommendations

Issue A: The test result reporting page does not provide enough context to let the user understand the types of tests acceptable for registering into the system.

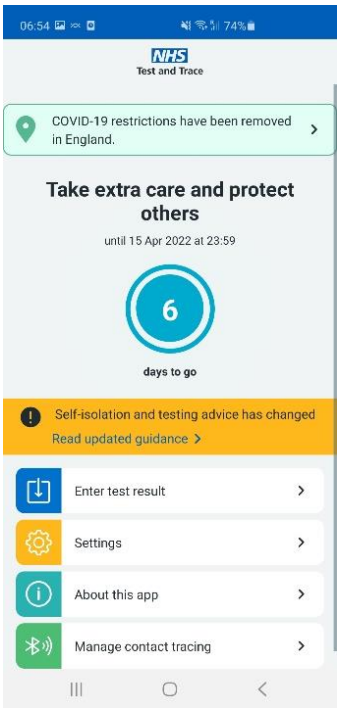


Heuristic #4: Consistency and standards

General findings: The application layout and colours used do not deviate, utilizing related patterns and a consistent blue colour as the primary colour for background, text, links, etc.

Negative Findings & Recommendations

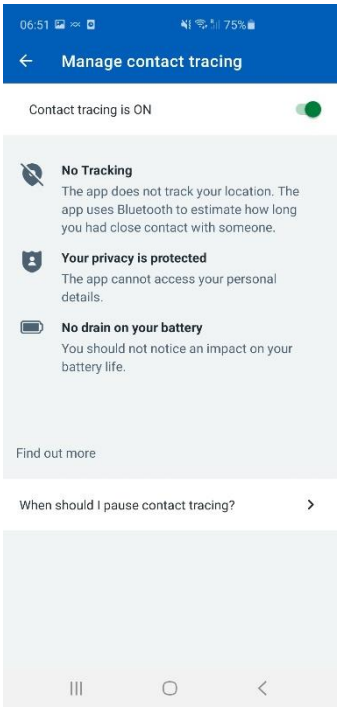
Issue A: Upon navigation to the settings of the application for the first time, the layout of the navigation buttons differentiate from other navigation buttons such as the ones located in the homepage. Thus the same design can be applied, comprising for instance the inclusion of icons.



Heuristic #5: Match between system and the real world

Negative Findings & Recommendations

Issue A: A digitally illiterate person or new user would have a challenging time connecting the icon with the action of the navigation button for registering a test result, as the utilization of an input icon is too vague. Associating testing performed with lab associated equipment in the form of an icon could potentially advance a greater visual comprehension at first glance.



Heuristic #6: Flexibility and efficiency of use

General findings: No shortcuts have been identified in the application.

Negative Findings & Recommendations

Issue A: Whilst the user navigates through the application, venturing deep, the sole manner to reach back to the homepage is by pressing the back button one page at a time. An issue like this is easily solvable with the introduction of a clickable logo icon or homepage icon.

STEP 4 (PART II): EVALUATION OF THE NHS COVID-19 APP

Clipboard | Font | Alignment | Number

Y159

	A	B	C	D	E	F	G	H	I	J	K	L
1	PID	FID	DATE	CONTENT	RATING	VERSION		REVIEW TYPE		COMMENT 1	COMMENT 2	COMMENT 3
2	P1	G1	09/04/2022	Staff are run off there fe	5			Negative review		-	-	-
3	P2	G2	08/04/2022	When you phone some c	1			Negative review		Emergency line	-	-
4	P3	G3	07/04/2022	Very good thank you	5	3.6.1 (70)		Positive review		Good app	-	-
5	P4	G4	07/04/2022	Ilove	5	4.27 (297)		Positive review		Good app	-	-
6	P5	G5	06/04/2022	Can't get in! Every time I	1	4.27 (297)		Negative review		Incorrect	User gets	-
7	P6	G6	05/04/2022	Waste of time, our mone	1			Negative review		Privacy concerns	-	-
8	P7	G7	05/04/2022	App was easier than exp	4	4.27 (297)		Positive review		Ease of use	-	-
9	P8	G8	05/04/2022	Good to have good mobi	5	4.26.2 (28		Positive review		Good app	-	-
10	P9	A1	05/04/2022	^.	1	4.27		Junk review		-	-	-
11	P10	G9	04/04/2022	great app need to add m	5	4.27 (297)		Positive review		Implement	-	-
12	P11	G10	04/04/2022	A good idea but execute	3	4.27 (297)		Neutral review		Test results	-	-
13	P12	G11	04/04/2022	Excellent	5	4.27 (297)		Positive review		Good app	-	-
14	P13	G12	04/04/2022	Keep closing.keep stopp	1	4.27 (297)		Negative review		User gets kicked	-	-

FIGURE C3 – Coding of user reviews

A separate evaluation of the application was conducted by utilizing feedback received user reviews in the Google Play Store and Apple Store. A thematic analysis approach was commenced by initially downloading on the 10th of April 2022, all publicly available user reviews from both app stores using the Heedzy online tool. The Heedzy tool permitted the extraction of additional information besides the content of the review, including the date and rating of the review, as well as the version of the application used by the individual leaving the review. Evidently, 24010 reviews were collected from both app stores, with 19072 reviews from the Google Play Store and 4938 reviews from the Apple Store. Desiring to filter the reviews to match relevancy with the latest version and taking into consideration the imbalance in the distribution between the two app stores, a sample of the 500 most recent reviews was drawn, covering the months of January, February and March.

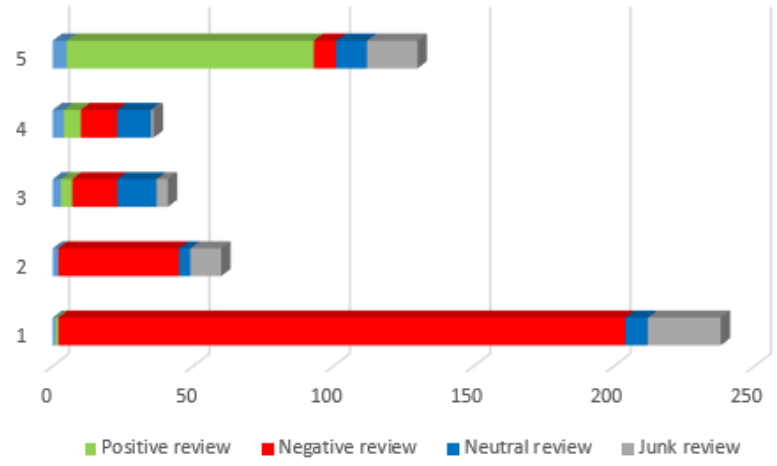


FIGURE C4 – Comparison between user review types sorted by allocated user review ratings

Managed using Microsoft Excel, the user reviews were manually labelled as positive, negative, neutral or junk in accordance with the contents of each review. Despite the identification of unevenness between positive and negative reviews, balancing the categories was omitted due to the negative reviews majorly outnumbering the positive reviews.

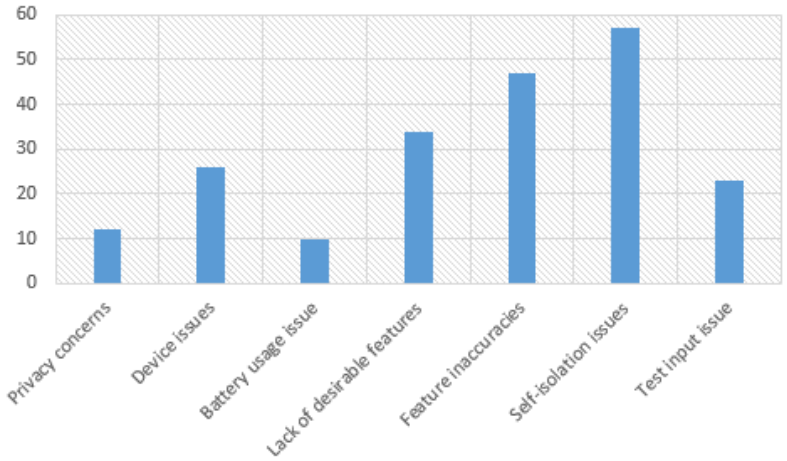


FIGURE C5 – Comparison between usability issues

Meanwhile, the user reviews were further manually coded, by recording brief comments about the contents of each user review. Upon summarization, the codes were skimmed for patterns with relevance to usability issues, resulting in the development of seven distinctive categories.

USABILITY ISSUES OF COVID-19 APPLICATION

Battery usage issue: Continuous operation of the application causes the mobile battery to drain quickly. Users have stated that the "Bluetooth [technology] uses too much battery power" [P303] and that "location services impose a heavy drain on [the] battery" [P146], since the application "does not work without location services" [P146].

Lack of desirable features: Complaints and requests have been raised towards the developers about the re-implementation of a previously removed feature called Venue check-in. Some users have expressed that "vulnerable people still want to be aware" of "who's got COVID" [P143], and "preferred the scanner to have remained in order to scan the QR code on entering pubs, clubs, etc." [P85], essentially suggesting the feature to "still being included within the app" [P79].

Dissatisfaction was further expressed by the inability to enter results concerning rapid flow (RFT) test results, lateral flow (LFT) test results and in particular negative Polymerase Chain Reaction (PCR) test results. "There needs to be a way to register LFT results and negative PCR results" [P439] and "it would be a lot better if we could register rapid flow tests" [P293], are some of the reviews left by users in question of the application's purpose to protecting others.

Feature inaccuracies: The exposure notification system notifying users of exposure to potentially infectious individuals does not work as expected. Incidents transpire where a user's partner "registered a positive covid result … and the app hasn't pinged [the user] to say [he has] been near her" [P97], a family member "isolating for covid and [the app] doesn't work" [P188], or users that know that they have "come into contact with an [individual] … that had a positive PCR test … and [the user] was not notified" [P158].

Self-isolation issues: When the application sets the status of a user to self-isolation, the user cannot make any adjustments to the self-isolation progress and subsequently present the user as an infectious individual to others till the isolation ends. Despite government guidance stating the ability to end isolation through testing, "there is no function to add … LFTs" whilst positive tests do "not sent a code to enter [the] result … so the data cannot reflect [the] progress to come out of isolation" [P200]. Thus the "isolation countdown … can only stop by deleting all the data or uninstalling the app" [P222], leading to loss of interest in the app.

Not only that, but the countdown commencement for self-isolating is also not in accordance with the date of reporting symptoms experienced and tests conducted. “App starts isolation period from the date the [test] code is entered” [P178] rather than “from the date of positive test or start of the symptoms” [P185]. Users demand to being “able to put in date of test/symptoms … if you are late to” [466] report them on the date received or conducted.

Privacy concerns: Uncertainty towards the trustworthiness of the application was a common encounter by the user’s comments. The tracking approaches are misinterpreted by users, thinking that the application “knows exactly where everyone is” [P406] as “it tracks everywhere you go” [P241] or rather “spying on you” [P241], or “when you been in contact with someone who got covid … that person scams [the user’s] identity” [P320]. With the app requiring “access to everything on the device” [P92], users become more sceptical about the possible uses to invading their privacy.

Device issues: The application appears incompatible with some devices at which users cannot operate the application or even download it. “Doesn’t work on Huawei phones” [P326], “if … iPhone is 6 or earlier … it will not download” [P216], “[Google Pixel 6] doesn’t support [feature]” [P219], “won’t … install as it’s too big for … phone” [P469] and “pending to download” [P275], are some of the encounters by users.

Test input issue: Confusion clouds individuals when it comes to the registration of test results, a product of insufficient clarification of acceptable tests or potentially caused by an unknown system error. Users question the inability to “enter a lateral flow test result in the app” [P352] and how the “8-character code is only given for positive results” [P91]. In other scenarios, users seem to baffled at the encounter of error messages stating that the “code is not recognised” [P292] or “code not recognised or may have expired” [P247], despite the attempt of register acceptable test types.

STEP 5: ITERATION OF REQUIREMENTS LIST

The preliminary list of requirements is reassessed based on the usability issues identified through the evaluation conducted on the NHS COVID-19 application and respective user reviews. Overall the new findings did not deviate or contradict previously acknowledged requirements, thus combining the old and new requirements established.

REQ ID	NAME	DESCRIPTION	PRIORITY
FR1	Report symptoms	Users must be able to report any symptoms experienced at the present time	High
FR2	Risk score system	The application should inform the user of the likelihood of getting infected by COVID-19	Medium
FR3	Guidance provision	The application should provide a broad variety of information including news, suggestions, instructions, etc.	High
FR4	Language selection	The application should be available in all languages and be accessible to individuals with disabilities	Low

FR5	Medical records	Users should be able to link and manage NHS medical records through the application	Medium
FR6	LFT / RFT / PCR reporting	The user should be permitted to report any LFT / RFT / PCR test result. A digital test result code is to be provided regardless of the result status	High
FR7	Logs	Actions executed in the application such that is symptom or test reporting, should be recorded and accessible for modification	High
FR8	Venue check-in feature	A feature that permits a user to scan and create a QR code used to check into a venue.	High
FR9	Data deletion	Application should permit user to delete data at any instance	High
FR10	Postcode login	The application should request upon registration the user's postcode district.	High
NFR1	Voluntary system	Downloading and using the application should be completely voluntary. The user should also be in control of turning off or deletion of the application and/or the data	High
NFR2	Notification privacy	Contacts reported to the user as potentially infectious individuals should have their privacy preserved	High

STEP 6: PROTOTYPING

The design objectives set out in the newest iterated list of requirements was made usage to come up with a new design for the NHS COVID-19 application. An interactive high-fidelity prototype was to be developed using a previously familiar and common tool called Adobe Xd, at which the prototype design would use the original application as the basis for the new design. Doing so would speed up the process of development and ensure that the design does not potentially diverge as in accordance with the findings from the evaluation of the NHS COVID-19 application, the elements and layout of the application's user interface are of good quality.

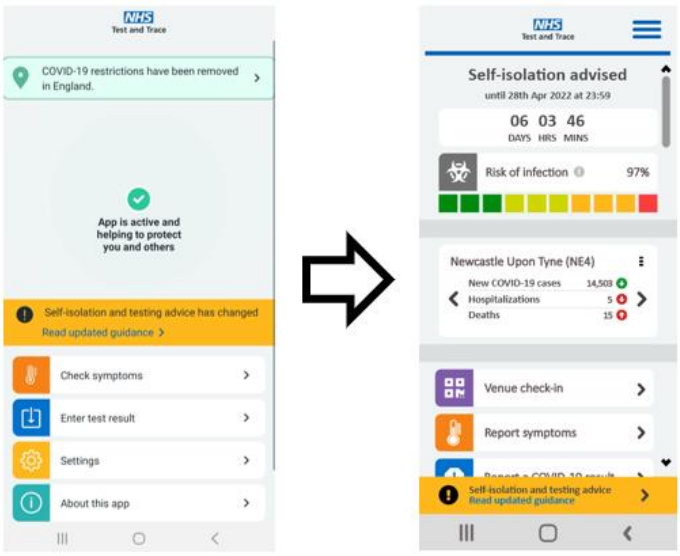


FIGURE C6 – Comparison between NHS COVID-19 app and prototype

In the complemented figure, an example transformation of the Homepage screen can be envisioned where some of the applied requirements can be immediately identified, such that is the addition of a risk score system [FR2], addition of guidance in the form of local news [FR3] and implementation of a venue check-in feature [FR7].

SECTION D: RESULTS AND EVALUATION

PROJECT OUTPUT & REQUIREMENTS

FIGURE D1 – Loading screen

Description: Launching the application pops up a loading screen.

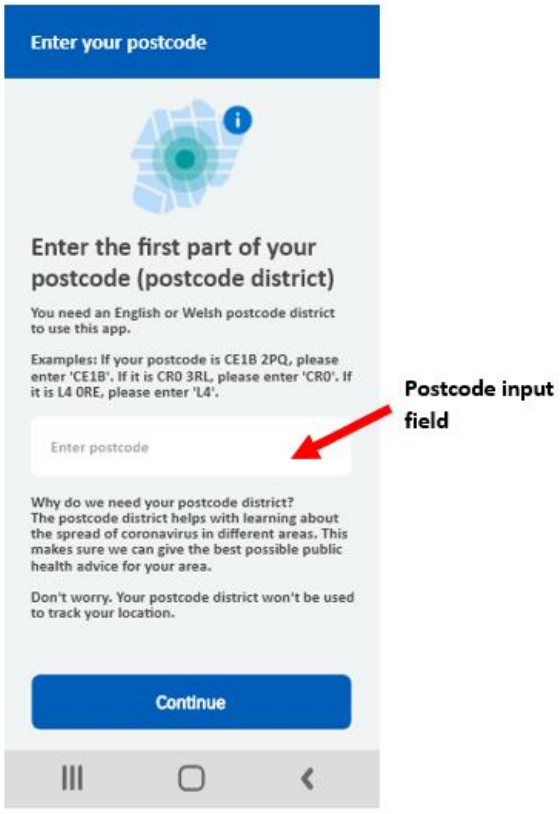


FIGURE D2.1 – Login screen

Description: When the user launches the application for the first time, this screen pops up after the loading screen, requesting from the user to enter the first part of the user's postcode.

Covers functional requirements FR10

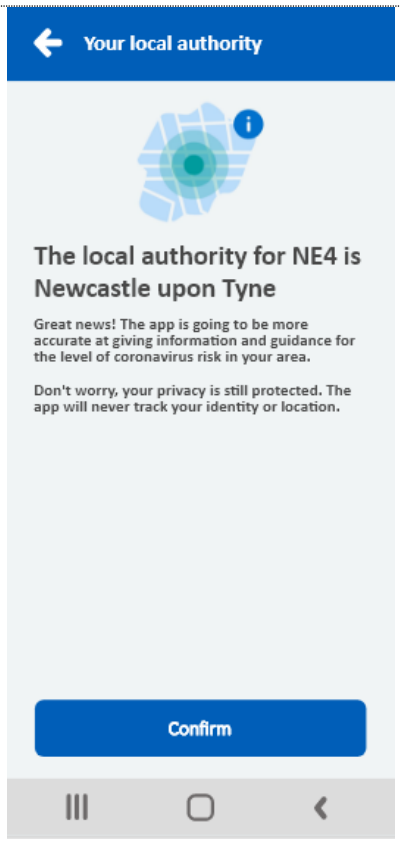


Figure D2.2 – Login screen 2

Description: Upon registering a postcode district, the user is redirected to this screen to confirm the local authority identified.

Covers functional requirements FR3

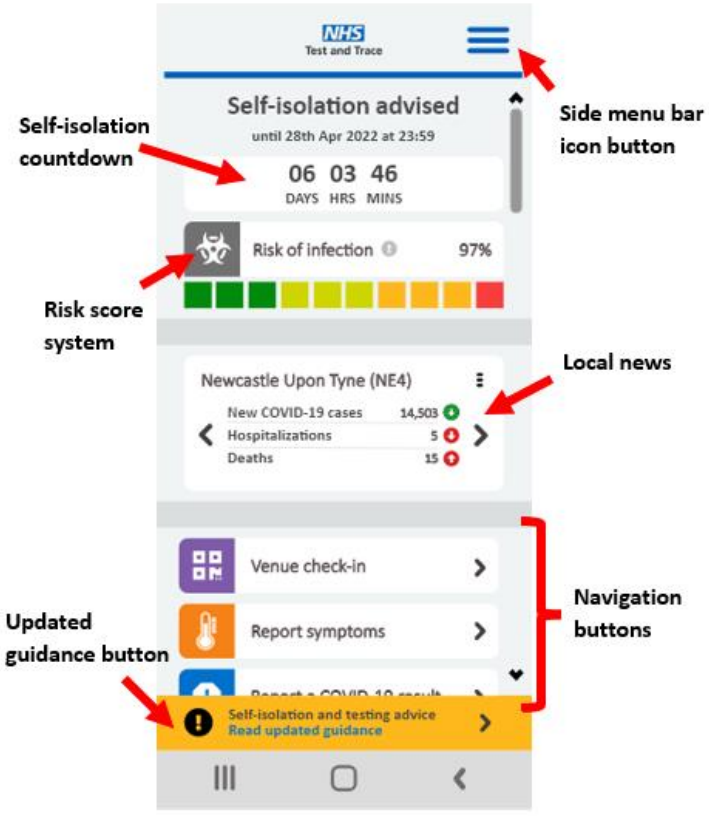


Figure D3.1 – Homepage screen

Description: Upon logging into the app, the user gets redirected to the homepage screen, from which the user can navigate the application as well as check for guidance information, COVID-19 news and exposure updates.

Covers functional requirements FR2, FR3

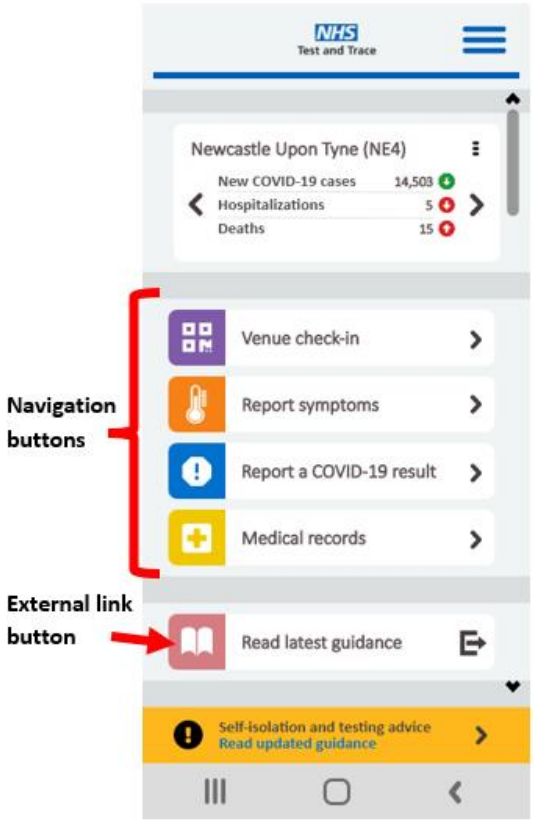


FIGURE D3.2 – Homepage screen

Description: Scrolled down showcase of the homepage screen.

Covers functional requirements FR1, FR3, FR4, FR5, FR8.

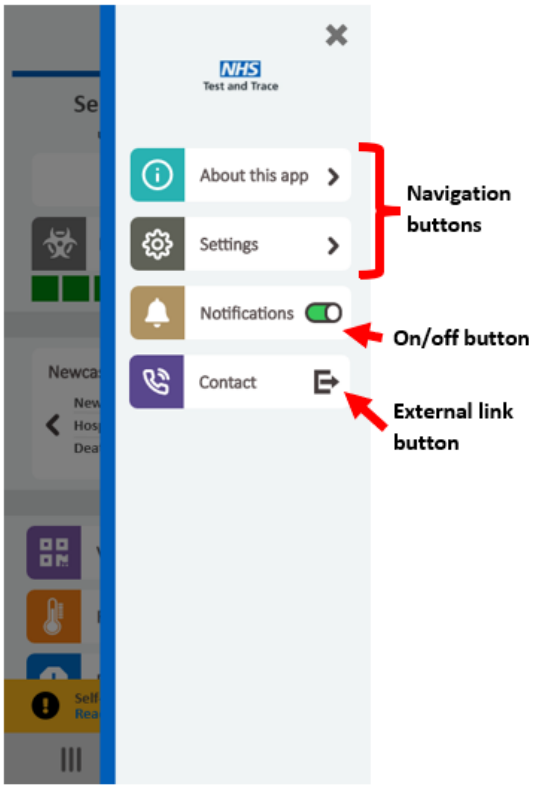


FIGURE D4 – Side menu bar screen

Description: Pressing the side menu bar icon button in the homepage pops a right-hand side menu bar, offering the user additional navigation options in addition to the ability to turn on/off app push notifications on the user's device.

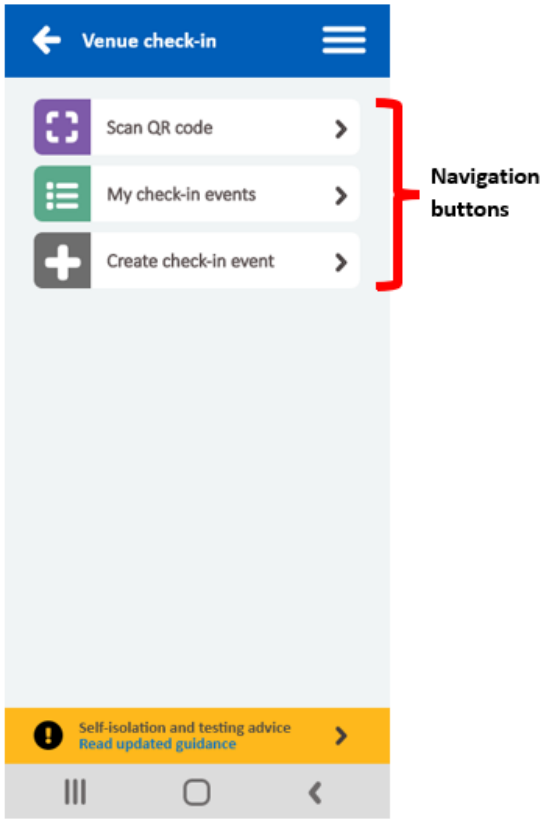


FIGURE D5.1 – Venue check-in screen

Description: Pressing the "Venue check-in" navigation button in the homepage redirects the user to this screen from which the user is permitted to scan a QR code of a check-in event, check all recent check-in events or create a new check-in event.

Covers functional requirements FR8

FIGURE D5.2 – Scan QR code screen

Description: Pressing the "Scan QR code" navigation button in the Venue check-in screen activates the usage of the device's camera in order to scan the QR code of a check-in event.

Covers functional requirements FR8, FR3

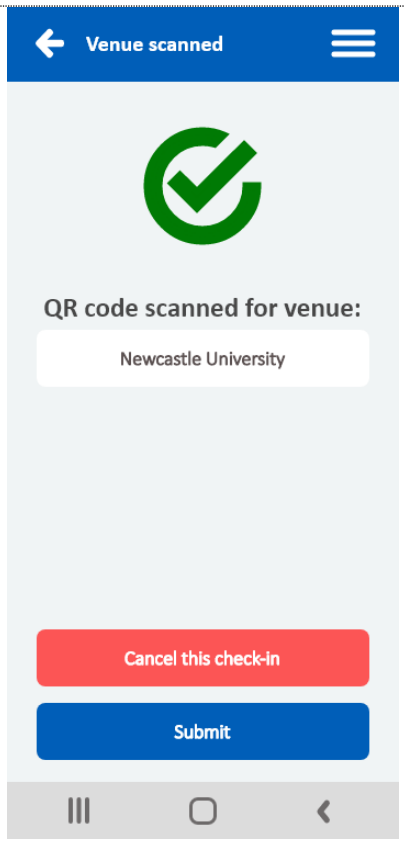


FIGURE D5.3 – Venue scanned screen

Description: Upon scanning of a venue check-in event, the user is redirected to this screen to confirm the venue scanned.

Covers functional requirements FR8

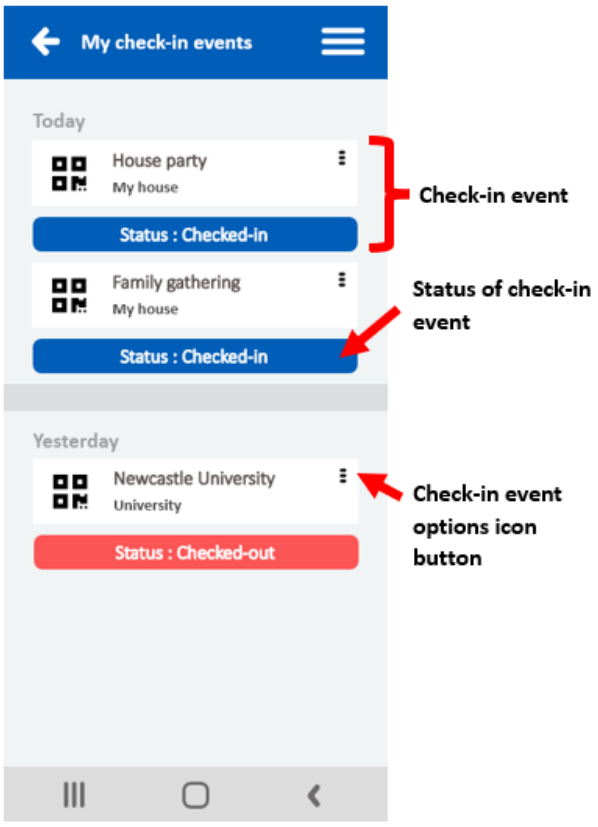


FIGURE D5.4 – My check-in events screen

Description: Pressing the "My check-in events" navigation button in the Venue check-in screen, redirects the user to this screen from which the user can administer and view all check-in events registered on the application.

Covers functional requirements FR8, FR9

FIGURE D5.5 – View check-in event screen

Description: Pressing any check-in event from the My check-in events screen, redirects the user to this screen from which the user can check in/out of a venue, as well as view, edit or print the details the check-in event.

Covers functional requirements FR8, FR9

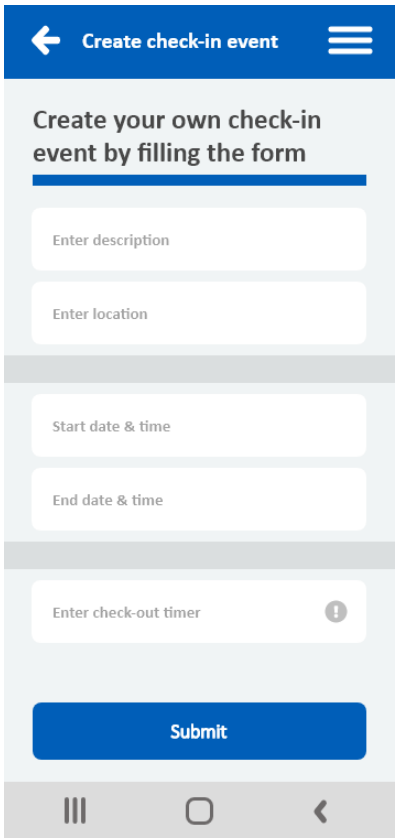


FIGURE D5.6 – Create check-in event screen

Description: Pressing the "Create check-in event" navigation button in the Venue check-in screen, redirects the user to this screen from which the user can create a new check-in event by entering the description, location, date & time, and check-out timer. A check-out timer automatically checks out a user after checking into a venue.

Covers functional requirements FR8

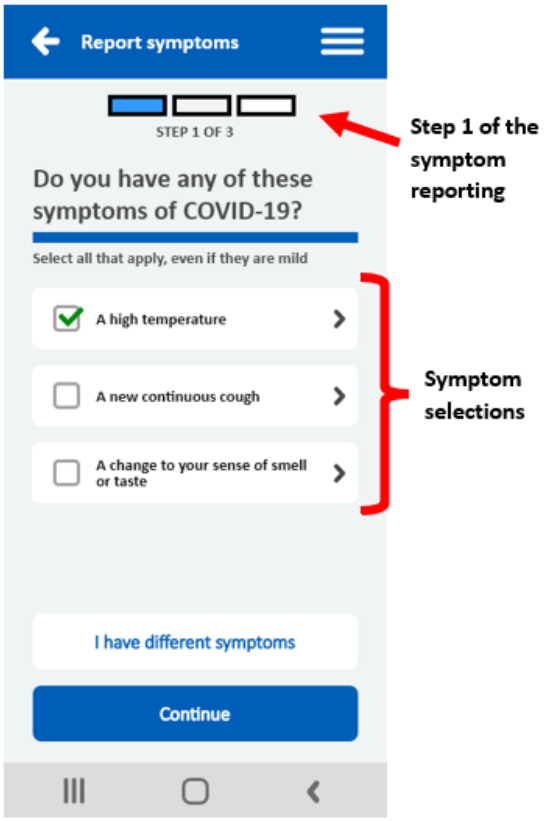


FIGURE D6.1 – Report symptoms screen

Description: Pressing the "Report symptoms" navigation button in the homepage redirects the user to this screen from which the user is permitted to select any symptoms experienced recently that match any of the pre-determined range of symptoms provided. In case the user does not have any of the symptoms showcased, the user can proceed by pressing the "I have different symptoms" button.

Covers functional requirements FR1

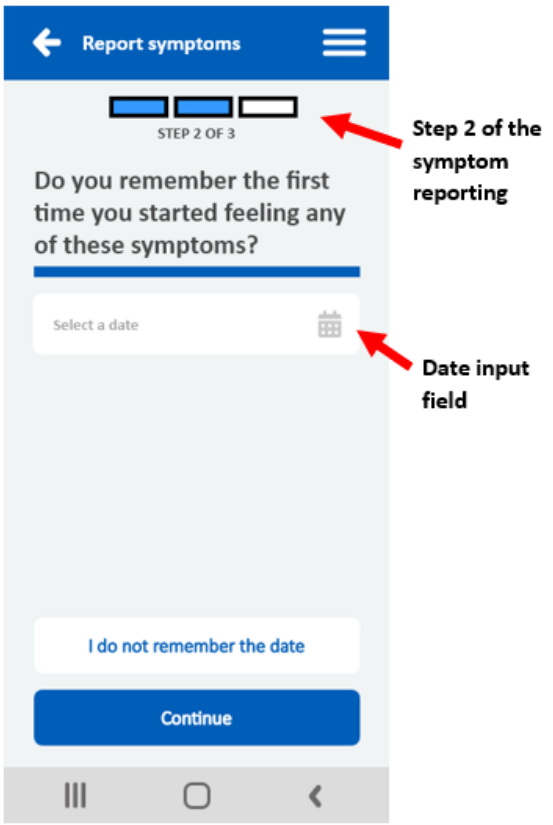


FIGURE D6.2 – Report symptoms screen

Description: When the user has selected at least one symptom in the first step of the symptom reporting screen, the user is redirected to the next step of the process where the user is requested to select the date the symptoms stated have emerged. In case the user has forgotten the date, the user can proceed by pressing the "I do not remember the date" button.

Covers functional requirements FR1

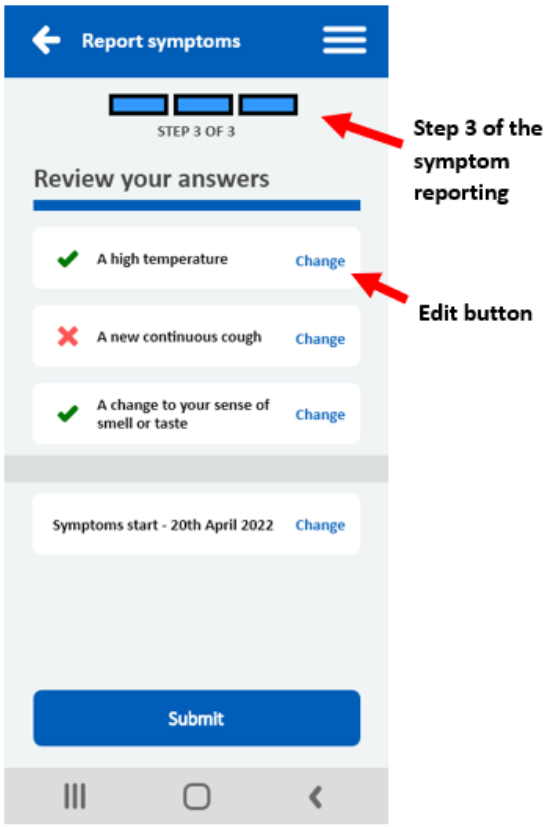


FIGURE D6.3 – Report symptoms screen

Description: Completing the previous steps of the symptom reporting screen, redirects the user to the final step of the process where the user can review and modify the responses of the previous steps.

Covers functional requirements FR1

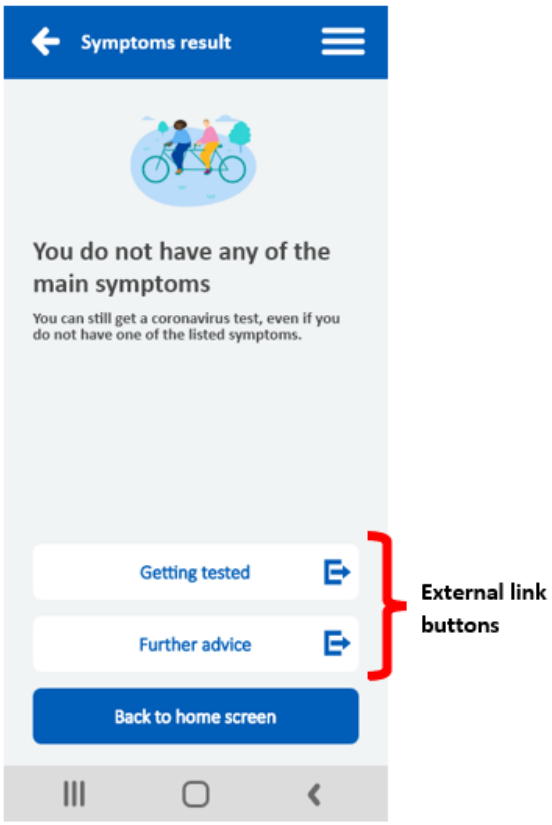


FIGURE D6.4 – Symptoms result screen

Description: Pressing the "I have different symptoms" button in the first step of the symptoms reporting screen, redirects the user to this screen from which the user is informed about the likelihood of a being infected with COVID-19.

Covers functional requirements FR3

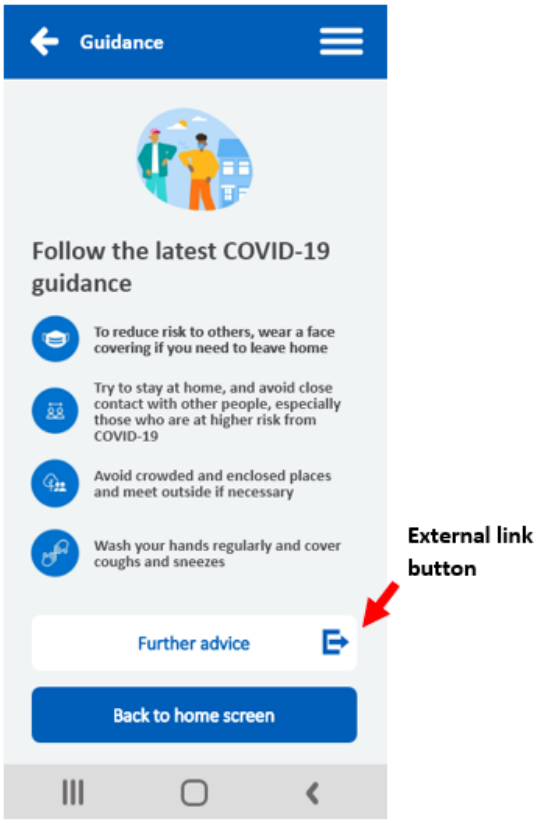


FIGURE D6.5 – Guidance screen

Description: Following the symptoms result screen, if the user is determined to be potentially infected by COVID-19, guidance about limiting the spread of the virus is provided.

Covers functional requirements FR3

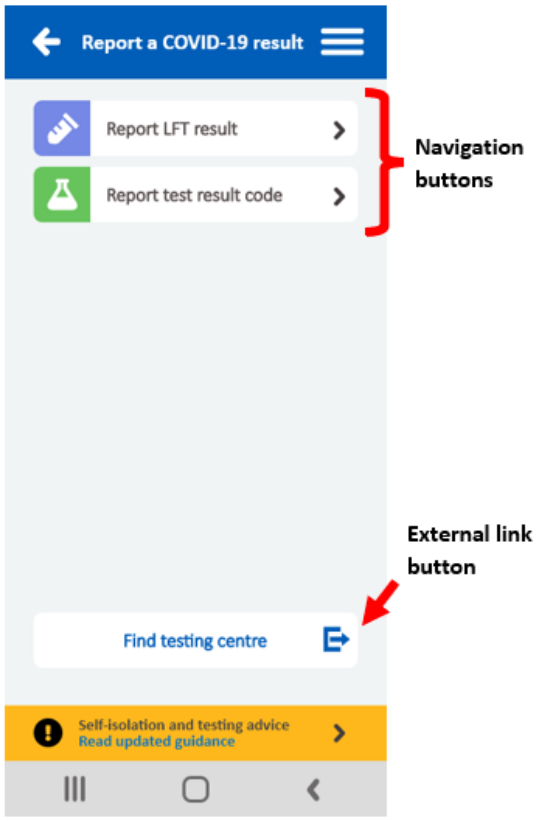


FIGURE D7.1 – Report a COVID-19 result screen

Description: Pressing the "Report a COVID-19 result" navigation button in the homepage redirects the user to this screen from which the user is permitted to report a LFT result or qualified test results, such that is a PCR or RDT result.

Covers functional requirements FR6

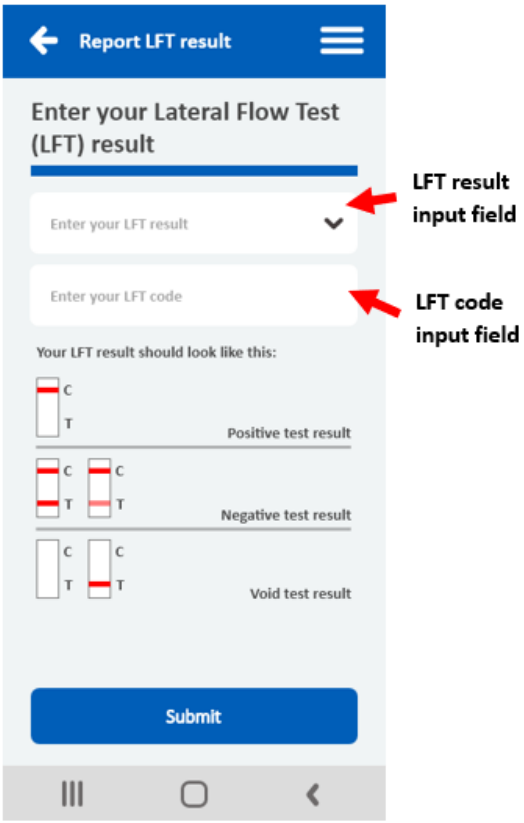


FIGURE D7.2 – Report LFT result screen

Description: Pressing the "Report LFT result" navigation button in the Report a COVID-19 result screen, redirects the user to this screen from which the user can report a LFT result by entering an LFT result with the corresponding code.

Covers functional requirements FR6, FR3

FIGURE D7.3 – Report test result code screen

Description: Pressing the "Report test result code" navigation button in the Report a COVID-19 result screen, redirects the user to this screen from which a user can report qualified test result codes received from public health authorities.

Covers functional requirements FR6, FR3

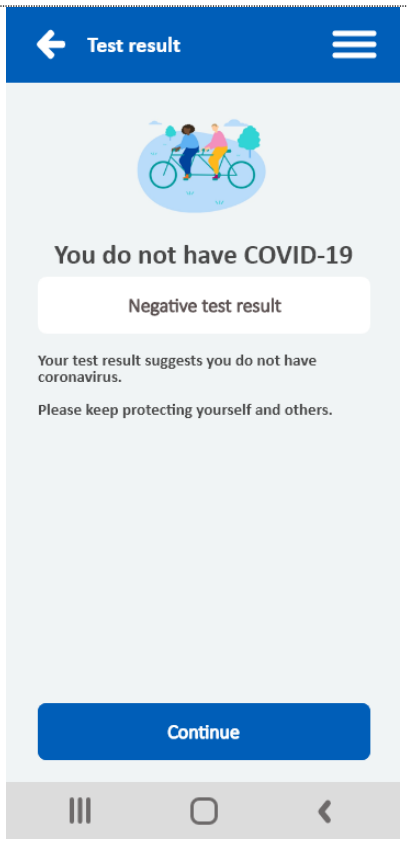


FIGURE D7.4 – Test result screen

Description: Upon reporting a test result, the user is redirected to this screen to envision the result of the test registered.

Covers functional requirements FR3

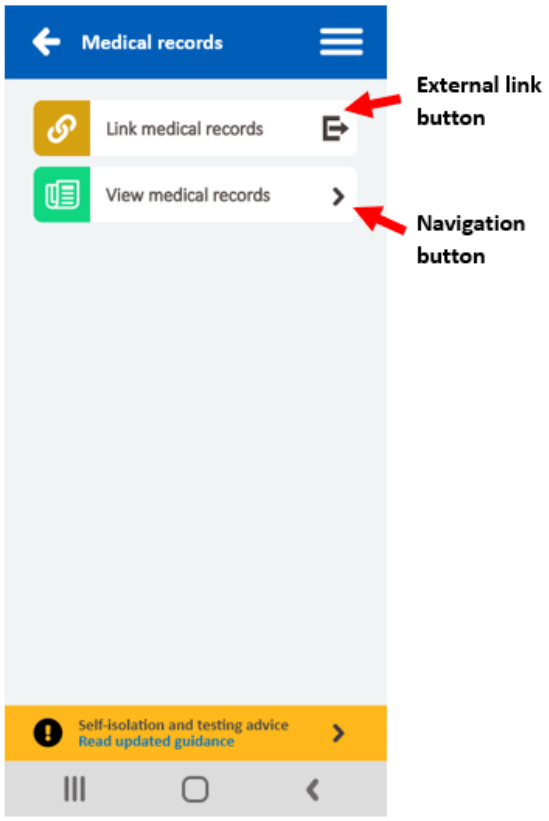


FIGURE D8.1 – Medical records screen

Description: Pressing the "Medical records" navigation button in the homepage redirects the user to this screen from which the user is permitted to link and view medical records with the application.

Covers functional requirements FR5

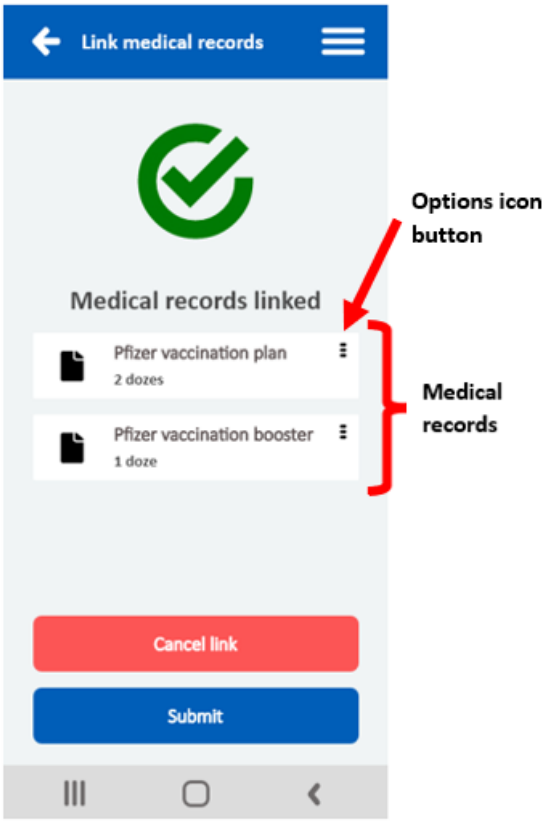


FIGURE D8.2 – Link medical records screen

Description: Pressing the "Link medical records" external link button redirects the user to a site at which the user is requested to login to an NHS account. Doing so will redirect the user back to this screen, where the user will be able to view relevant medical records.

Covers functional requirements FR5, FR9

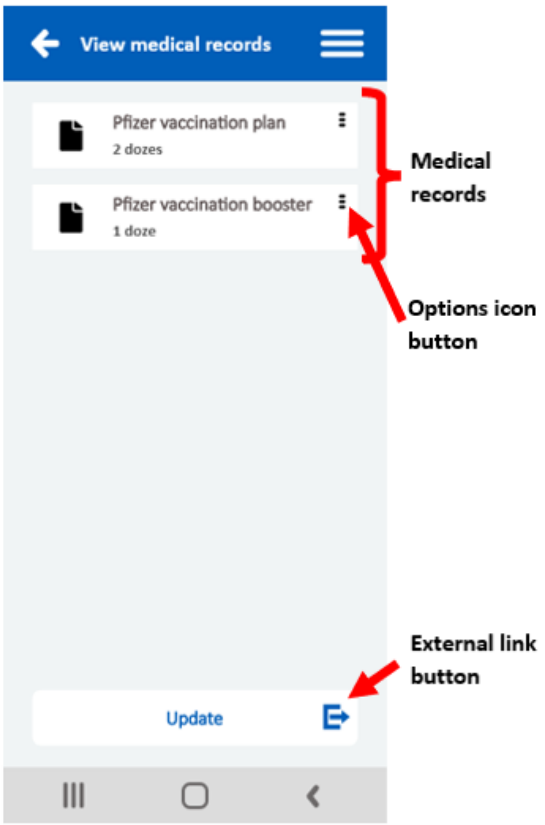


FIGURE D8.3 – View medical records screen

Description: Pressing the "View medical records" navigation button from the Medical records screen, redirects the user to this screen from which the user can view all relevant medical records that have been linked with the application.

Covers functional requirements FR5, FR9

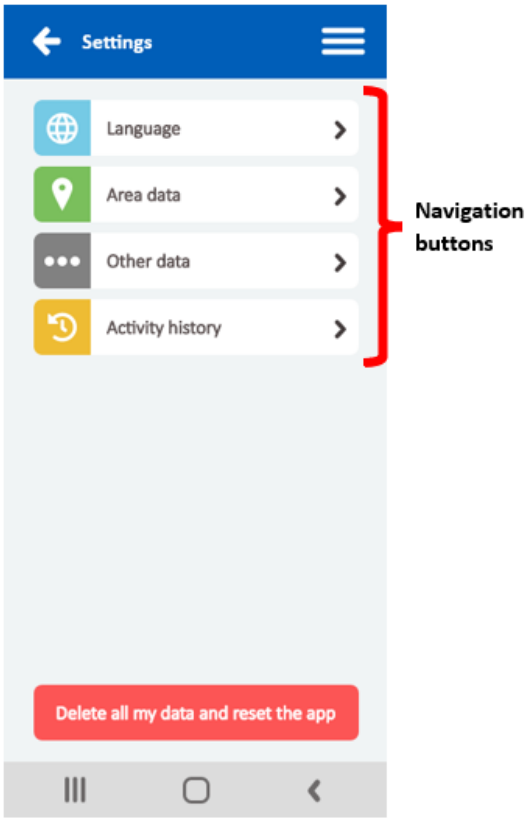


FIGURE D9 – Settings screen

Description: Pressing the "Settings" navigation button from the right-hand side menu bar, redirects the user to this screen from which the user can change the system language and manage various data.

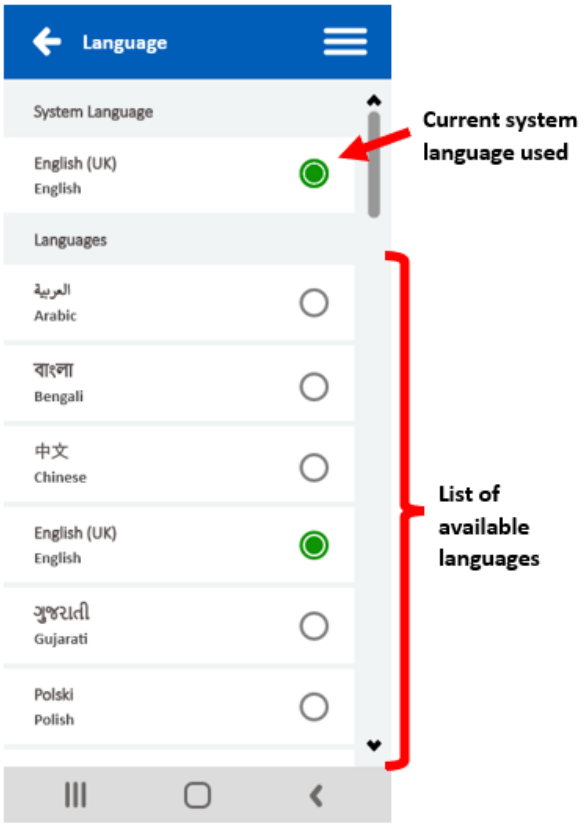


FIGURE D10 – Language (Settings) screen

Description: Pressing the "Language" navigation button from the Settings screen, redirects the user to this screen from which the user can select a different system language.

Covers functional requirements FR4

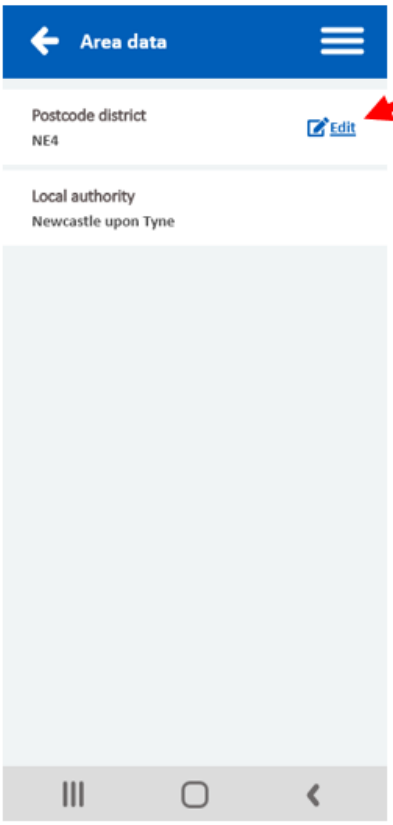


FIGURE D11 – Area data (Settings) screen

Description: Pressing the "Area data" navigation button from the Settings screen, redirects the user to this screen from which the view and edit the postcode district registered into the system.

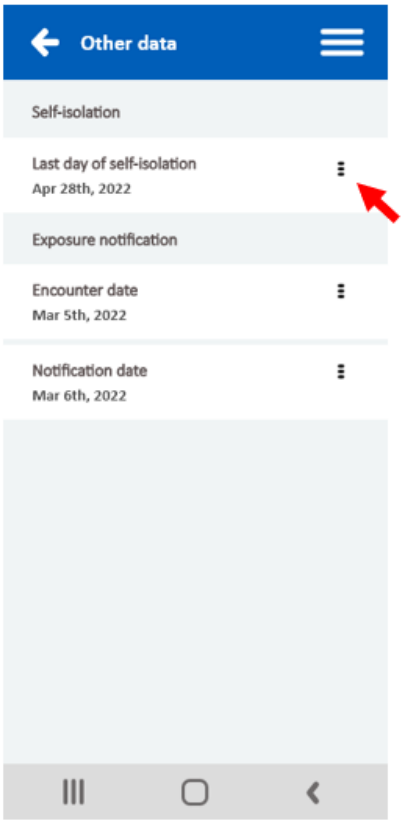


FIGURE D12 – Other data (Settings) screen

Description: Pressing the "Other data" navigation button from the Settings screen, redirects the user to this screen from which the user can view and manage data such that may concern self-isolation and exposure.

Covers functional requirements FR9

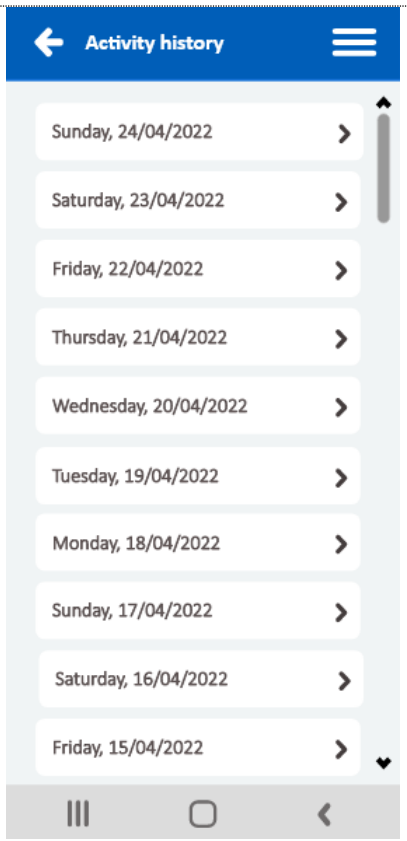


FIGURE D13.1 – Activity history (Settings) screen

Description: Pressing the "Activity history" navigation button from the Settings screen, redirects the user to this screen from which the user can view a desired date to view the logs of.

Covers functional requirements FR7

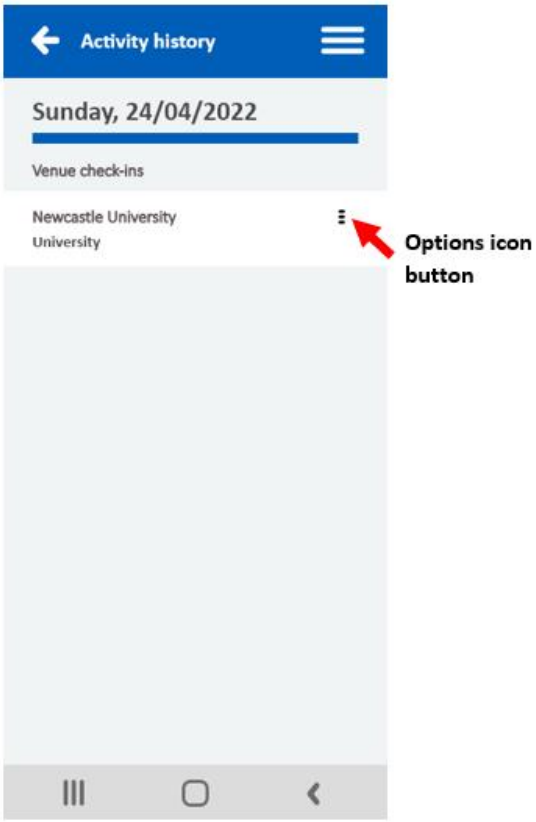


FIGURE D13.2 – Activity history (Settings) screen

Description: Pressing a navigation button of a corresponding date from the Active history screen, redirects the user to this screen from which the user can view the logs of venue check-ins, symptoms recorded, and tests reported.

Covers functional requirements FR7, FR9

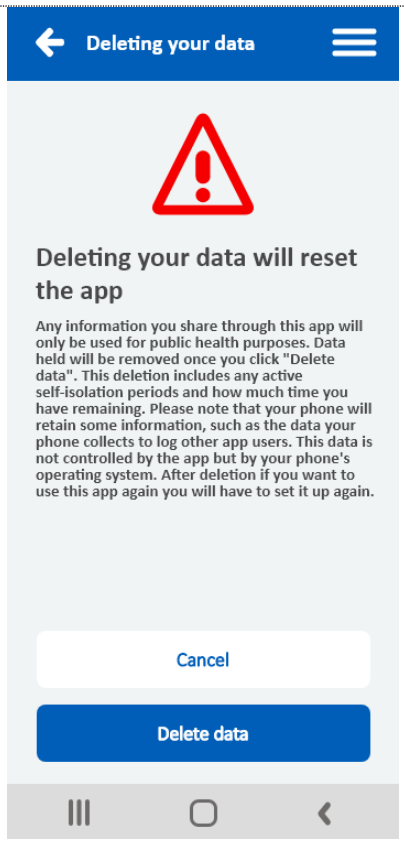


FIGURE D14 – Deleting your data (Settings) screen

Description: Pressing the "Delete all my data and reset the app" button from the Settings screen, redirects the user to this screen at which the user can delete all data stored on the application. Proceeding to do so will reset and restart the application from fresh.

Covers functional requirements FR9

EVALUATION OF THE PROTOTYPE

While a new design was in the works, a recruitment search was carried out via online platforms and personal networks, seeking out individuals to voluntarily participate in the evaluation of the prototype in works. A total of six participants from different backgrounds, have demonstrated interest and agreed upon a common date to conduct a cognitive walkthrough.

The plan for this evaluation encompassed two major activities: a cognitive walkthrough of a digital interactive prototype, followed by a discussion about the overall experience.

Activity #1: A copy of the prototype design was provided to participants, to carry out a sequence of detailed operations from the viewpoint of the persona developed previously in the project. The operations performed were as follows:

Goal A1 : Log into the app

- Wait for loading screen to disappear
- Enter the postcode district in the input field
- Press the "Continue" button
- Press the "Confirm" button

Goal B1 : Report a high temperature symptom experienced at the moment

- Navigate to the homepage (if not already)
- Press the "Report symptoms" button
- Select the symptoms that applies
- Press the "Continue" button
- Select the date the symptoms have emerged
- Press the "Continue" button
- Press the "Submit" button

Goal B2 : Scan a QR code to check-in to a venue (e.g. Newcastle University)

- Navigate to the homepage (if not already)

Goal B3 : Create a check-in venue event

- Navigate to the homepage (if not already)
- Press the "Venue check-in" button

- Press the “Venue check-in” button
- Press the “Scan QR code” button
- Align the shaded box area with the QR code to be scanned
- Press the “Submit” button

- Press the “Create check-in event” button
- Enter the description of the check-in event in the input field
- Enter the location of the check-in event in the input field
- Select the start date and time of the check-in event in the input field
- Select the end date and time of the check-in event in the input field
- Select the check-out timer of the check-in event in the input field
- Press the Submit button

Goal B4 : Check-out of a venue event (e.g. House party check-in event)

- Navigate to the homepage (if not already)
- Press the “Venue check-in” button
- Press the “My check-in events” button
- Press the label with description as “House party”
- Press the “Check-out” button

Goal B5 : Report a PCR test result code

- Navigate to the homepage (if not already)
- Scroll down
- Press the “Report COVID-19 result” button
- Press the “Report test result code” button
- Enter the test result code in the input field
- Press the “Submit” button

Goal B6 : Report a lateral flow test result

- Navigate to the homepage (if not already)
- Scroll down
- Press the “Report COVID-19 result” button
- Press the “Report LFT result” button
- Select the lateral flow test result applicable
- Enter the lateral flow test code
- Press the “Submit” button

Goal B7 : Link vaccination certificates to the app

- Navigate to the homepage (if not already)
- Scroll down
- Press the “Medical records” button
- Press the “Link medical records” button
- LOGIN STEPS (IGNORE)
- Press the “Submit” button

Goal B8 : View vaccination certificates in the app

- Navigate to the homepage (if not already)
- Press the “Medical records” button
- Press the “View medical records” button

Goal C1 : Change the postcode district

- Press the side menu bar icon (from anywhere within the app)
- Press the “Settings” button
- Press the “Area data” button
- Press the Edit button
- Enter the new postcode in the input field
- Press the “Continue” button
- Press the “Confirm” button

Goal C2 : Change the system language to Polish

- Press the side menu bar icon (from anywhere within the app)
- Press the “Settings” button
- Press the “Language” button
- Press the polish language option box
- Press “Confirm” button

Goal C3 : View logs of the 24thApril 2022

- Press the side menu bar icon (from anywhere within the app)
- Press the “Settings” button
- Press the “Activity history” button
- Press the button corresponding to the requested date

Goal C4 : View exposure data

Goal C5 : Delete all data and reset the app

- Press the side menu bar icon (from anywhere within the app)
- Press the "Settings" button
- Press the Other data button

- Press the side menu bar icon (from anywhere within the app)
- Press the "Settings" button
- Press the "Delete all my data and reset the app" button
- Press the "Delete data" button

Goal C6 : Turn off app notifications

- Press the side menu bar icon (from anywhere within the app)
- Press the "Notifications" button

Participants were requested while performing operations, to record or think aloud any issues encountered with relevance to usability. By reaching the end of an operation, participants were posed with four questions concerning the effect, meaning, outcome and visibility of an operation, and based on the experience provide a satisfaction rating on a scale from 1 to 5.

Activity #2: Concluding the evaluation of the prototype, participants were rounded up and given the opportunity to share and discuss with the group, their overall experience with the product, and gain a broad insight of any mutual feelings between participants.

FINDINGS OF THE EVALUATION

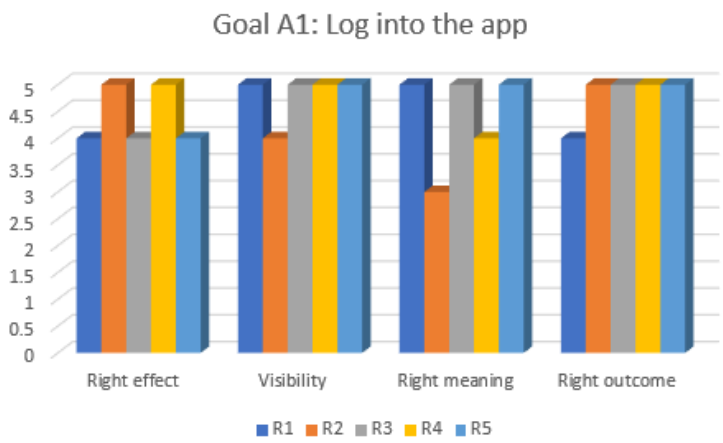


FIGURE C15 – Comparison between ratings allocated by the five participants

Rather than looking at individual ratings for the identification of issues, all ratings allocated for an operation were summed up and put side-by-side, permitting examination of results across all aspects. An example envisioned in the figure of the operation A1, is observed to utterly positive.

Overall, upon processing of all operation ratings, findings have not led to the discovery of any patterns, as satisfaction readings have been beyond adequate.

Despite findings from the ratings being unsuccessful in the discovery of any issues, participant observations have led to discovery of some areas of interest requiring further investigation. The following are some of the critical comments shared by participants during the evaluation:

Comment #1 – "*I cannot help but feel that there needs to be a way to register your close ones as the check-in feature would not be convenient in doing so …. not to mention that there is no way to report yourself as a contact of an infected individual*"

Comment #2 – *"If I do not have any of the symptoms listed but do experience symptoms of new variants … shouldn't an open-ended option be available"*

POLISHING THE PROTOTYPE

From the evaluation findings, amongst some minimal adjustments to be undertaken, a new feature concept emerged. This feature would permit users to register close friends and family members with which interactions can occur outside of check-in events, and exposure to COVID-19 cannot be identified otherwise. This new feature was brough to life in the form of a contacts feature that would permit one user to add another through the generation and sharing of a unique code. Thus the process does not involve the sharing of any personal information whilst consent is provided upon interaction.

The contacts feature would be accessible through the homepage of the application, and upon navigation the user would be permitted to add and manage registered contacts. Concept of this design can be visualised in the figure below.

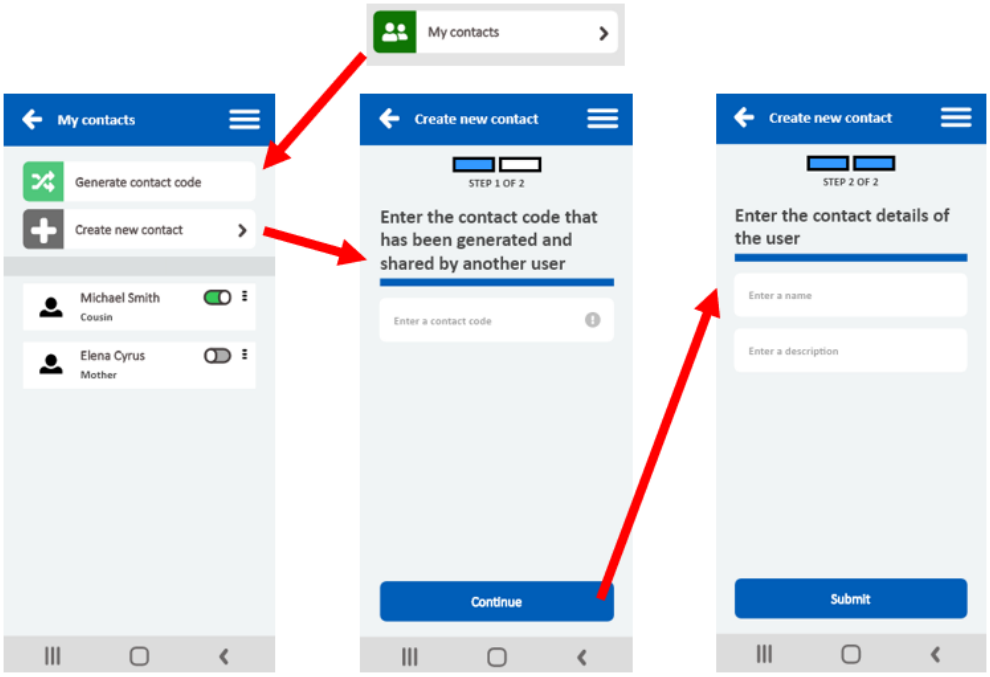


FIGURE C16 – Prototype concept design of a contacts feature

Nonetheless, the aforementioned featured remained as a concept and not an actual implementation, due to concerns ranging from potential misuse, ambiguities including exposure notifications from undesirable contacts, ease of use, and so on.

EVALUATION OF DEVELOPMENT PROCESS

The nature and straightforwardness of the project enabled for immense flexibility and stability over the entirety of the process. Fundamentally, the project revolved around the construction of a list of functional and non-functional requirements deriving from an extensive background research on track and trace applications and findings from an in-depth and iterative evaluation of the NHS COVID-19 application.

Setting off from the evaluation of the NHS COVID-19 application, on the surface, this seemed like an easy to do process although lack of comprehension and knowledge of what evaluation techniques work best in practice and which ones draw better results, was undoubtedly a challenge. Theory and execution can differentiate at times from person to person, and even though valuable findings have been extracted, especially from the analysis of user reviews, uncertainty clouds the success of the methods employed in this phase. On another note, the evaluation process could have been further enhanced by instead of

focusing on the singular evaluation of the NHS COVID-19 app, instead widen the horizons by evaluating a sequence of DCT applications in the space. Doing so would unquestionably provide insight beyond issues confronted by a sole approach and explore how users feel towards a range of DCT approaches.

Prototyping on the other hand was a recognizable stage due to the undertaking of similar HCI related projects. Once the requirements were obtained and prepared, converting them into actual designs was solely a matter of time. As DCT applications have been around for a while, implementation of features not included within the application could be easily fabricated with consultation of the approaches followed by other DCT applications. In the case of the check-in venue feature for instance, Germany's DCT application called Corona-Warn, was downloaded and explored to visualise the potential usages of such a feature.

Last but not least, evaluating the prototype was a disappointing experience as findings did not contribute towards any discoveries. An evaluation conducted by non-expert users did not support breakdown the prototype design to a deeper extend, measuring the decision choices and receiving constructing feedback with recommendations and alternative solutions to the design. Other than that, dealing with participants and having a leading role on a product produced by my person was truly informative.

In general, the technical aspect set out in the preliminary phase of the project was carried out with precision, minimum deviations and no major problems.

SECTION E: CONCLUSIONS

PROJECT OVERVIEW

Judging upon the end artefact aimed to be accomplished since the commencing of this project, an individual could state that this project was a success for the most part. Undertaking of the different development phases was predominantly smooth without any major hurdles to be conquered, completing the end goals set by focusing at one task at a time, dedicating pure hard work with consistency and precision.

OBJECTIVES ACCOMPLISHMENT

Objective #1: Review literature on track and trace applications and systems to produce a list of requirements

Successfully produced a list of functional and non-functional requirements that derived from an elaborated comprehension of existing approaches to dealing with contact tracing, and measuring the trade-offs between each approach.

Objective #2: Review literature on evaluation techniques and select suitable methods to be carried out

Successfully selected evaluation techniques matching the needs of the project, by investigating and documenting thoroughly the approaches incorporated by similar studies in the space.

Objective #3: Evaluate the NHS COVID-19 application to produce an iterated list of requirements

Successfully produced a new list of requirements based on findings drawn from a heuristic non-participant evaluation of the NHS COVID-19 application and a thematic analysis of the respective user reviews. The findings could have been improved overall by employing an evaluation conducted by other individuals, leading to the uncovering of any additional usability issues that could have been potentially omitted.

Objective #4: Develop a high-fidelity prototype or wireframe based on the requirements list

Successfully developed an interactive high-fidelity prototype using the prototyping tool Adobe Xd, encompassing each and every requirement set out by the iterated list of requirements. The prototype ensured the visualisation of the user requests, needs and concerns discovered through the evaluation findings.

Objective #5: Evaluate the high-fidelity prototype or wireframe to polish the prototype

Partially completed as evaluation findings from the cognitive walkthrough conducted with user participation, were insufficient and provided not any significant findings to make critical adjustments to the prototype. Uncertain as whether or not another evaluation technique could result in the discovery of different findings or if the project has produced a product of satisfactory level with users.

FUTURE WORK

Observation of the project aftermath recommends the desire for a more open-minded approach, releasing of constraints that prevent the development of a product intended for the public rather than on a personal level. Throughout the entirety of the project, decisive decisions and judgments could instead involve the participation of supplementary individuals, ensuring that personal preferences do not influence the

process of development. This could be achieved at various checkpoints of the process through the involvement of user participation, or even the expansion of user participation by having participants conduct a more collaborative and constructive approach, instead of controlling and manipulating the end result findings.

Speaking of the end artefact, rather than designing and developing a singular approach to tackling a desirable DCT application, ideally a sequence of designs each featuring a different approach could be the product for evaluation. By doing this, an evaluation of such a process would result in greater range of findings, leading to the selection of the most suitable approach amongst the designs. However, undertaking that kind of work consequently suggests considering multiple potential routes, indicating both centralised and decentralised DCT applications, evaluating a series of applications from both these categories.

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APPENDICES

Consent forms from participants

Newcastle University

Consent Form for Research Participant Group

Title of Study: DIGITAL CONTACT TRACING – AN EVALUATION OF THE NHS COVID-19 APPLICATION

Thank you for your interest in taking part in this research. Please complete this form after you have read the Information Sheet and/or listened to an explanation about the research study.

1.	I confirm that I have read the information sheet dated *20/04/2022 (Version 01)* for the above study, I have had the opportunity to consider the information, ask questions and I have had any questions answered satisfactorily.
2.	I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason, *[without my medical care or legal rights being affected]*. I understand that if I decide to withdraw, any data that I have provided up to that point will be *included.*
3.	I understand that no personal information will be collected as described in the information sheet dated *20/04/2022 (Version 01)*.
4.	I consent to my *anonymized* research data being stored and used by others for future research.
5.	I understand that my research data may be published as a report.
6.	I agree to take part in this research project.

By ticking this box, you consent to the aforementioned terms and conditions	✓

PARTICIPANT

Emma Kelly		25/04/2022
Name of participant	Signature	Date

RESEARCHER

Michalis Stavrou		25/04/2022
Name of researcher	Signature	Date

Consent Form V1.0 / Date 20/04/2022

Newcastle University

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2.	I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason, *[without my medical care or legal rights being affected]*. I understand that if I decide to withdraw, any data that I have provided up to that point will be *included.*
3.	I understand that no personal information will be collected as described in the information sheet dated *20/04/2022 (Version 01)*.
4.	I consent to my *anonymized* research data being stored and used by others for future research.
5.	I understand that my research data may be published as a report.
6.	I agree to take part in this research project.

By ticking this box, you consent to the aforementioned terms and conditions	✓

PARTICIPANT

Alexander Fiend		25/04/2022
Name of participant	Signature	Date

RESEARCHER

Michalis Stavrou		25/04/2022
Name of researcher	Signature	Date

Consent Form V1.0 / Date 20/04/2022

Newcastle University

Consent Form for Research Participant Group

Title of Study: DIGITAL CONTACT TRACING – AN EVALUATION OF THE NHS COVID-19 APPLICATION

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PARTICIPANT

Name of participant	Signature	Date
Helen Stavrou	[signature]	25/04/2022

RESEARCHER

Name of researcher	Signature	Date
Michalis Stavrou	[signature]	25/04/2022

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PARTICIPANT

Name of participant	Signature	Date
Angel Lawrence	Lawrence	25/04/2022

RESEARCHER

Name of researcher	Signature	Date
Michalis Stavrou		25/04/2022

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PARTICIPANT

CHRISTINA FURLDOU		25/04/2022
Name of participant	Signature	Date

RESEARCHER

Michalis Stavrou		25/04/2022
Name of researcher	Signature	Date

Information sheet given during interviews

DIGITAL CONTACT TRACING – AN EVALUATION OF THE NHS COVID-19 APPLICATION

BRIEF SUMMARY

In response to the outbreak of the COVID-19 pandemic, several governments across the world have imposed a series of measures to combat the unwavering transmission of COVID-19, including the introduction of Digital Contact Tracing (DCT) apps.

DCT apps are becoming a prominent measure in monitoring individuals from the shadows whilst permitting life to carry on. With that being said, key to the effectiveness of DCT apps is their extensive and fruitful consumption by a relatively substantial portion of the population. Evaluating the effectiveness of a DCT app however is rather difficult as privacy preserving policies prevent the extraction of meaningful data about the actual usage of these apps.

One such app is the NHS Covid-19 app that currently covers the regions of England and Wales.

PURPOSE OF THE RESEARCH

Having the ambition of investigate deeper and uncover the full potential of these innovative tools, the research aims at conducting an in-depth and iterative evaluation of the NHS Covid-19 app, and based on findings come up with an alternative optimized design in terms of **user experience (UX)** and **user interface (UI)**.

This evaluation includes the conducting a user-based evaluation at which user participation is requested to evaluate the usability of a prototype design (produced using the prototyping tool Adobe Xd) by examining how easily particular tasks can be carried out by a new user. Any data collected from this evaluation will be completely anonymized and will subsequently be made usage to further optimize the prototype design.

INFORMATION COLLECTED

Please remark that no personal information will be collected at any given point, and thus the data collected from the evaluation will not be bound in any shape or form to anyone. The information will be strictly used and referenced for research purposes.

CONTACT INFORMATION

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Vasilis Vlachokyriakos (Supervisor) vasilis.vlachokyriakos1@newcastle.ac.uk

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