Public Adoption and Trust in the Covid-19 Contact Tracing App in the UK: A survey study

Liz Dowthwaite, Joel Fischer, Elvira Perez Vallejos, Virginia Portillo, Elena Nichele, Murray Goulden, Derek McAuley

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Abstract

Background: Digital contact tracing is employed to monitor and manage the spread of Covid-19. However, to be effective the system must be adopted by a substantial proportion of the population. Studies of (mostly hypothetical) contact tracing apps show generally high acceptance, but little is known about the drivers and barriers to adoption of deployed systems.

Objective: The aim of this study is to investigate adoption and attitudes towards the NHS Covid-19 smartphone app, the digital contact tracing solution in the UK.

Methods: An online survey based on the technology acceptance model (TAM2) with the added factor of trust was carried out with a representative sample of the UK population. Statistical analysis shows adoption rates, attitudes towards and trust in the app, compliance with self-isolation advice, and highlights differences for vulnerable populations (older adults and members of black, Asian, and minority ethnic (BAME) communities).

Results: Around half of the 1001 respondents had downloaded and kept the app, but more than a third either did not intend to download it or had deleted it. Significantly more BAME respondents had deleted the app, and significantly more older adults did not intend to download it. Reasons for uptake were broadly to help the NHS and other people, especially among older adults, although significantly fewer BAME agreed that they did so to help the NHS. Reported compliance with received notifications to self-isolate was high, but significantly lower than reported intended compliance without received notifications. Of those who had ever used the app, only a fifth understood that the decision to send self-isolation notification is automated by the app. There were a range of significantly more negative views among BAME participants, including lower trust in the NHS, whilst older adults were often significantly more positive. Respondents without the app reported significantly lower trust and more negative views towards the app and were less likely to report they understood how the app works.

Conclusions: Whilst compliance of the ~50% who have the app is fairly high, there are issues surrounding trust and understanding that hinder adoption and therefore the effectiveness of digital contact tracing, particularly amongst BAME communities. The study highlights that more needs to be done to improve adoption among groups who are more vulnerable to the effects of the virus to enhance uptake and acceptance of contact tracing apps.

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Background: Digital contact tracing is employed to monitor and manage the spread of Covid-19. However, to be effective the system must be adopted by a substantial proportion of the population. Studies of (mostly hypothetical) contact tracing apps show generally high acceptance, but little is known about the drivers and barriers to adoption of deployed systems.
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Methods: An online survey based on the technology acceptance model (TAM2) with the added factor of trust was carried out with a representative sample of the UK population. Statistical analysis shows adoption rates, attitudes towards and trust in the app, compliance with self-isolation advice, and highlights differences for vulnerable populations (older adults over 65 years of age and members of Black, Asian, and Minority Ethnic (BAME) communities).
Results: Around half of the 1,001 (50.9%, 95% CI:47.8-54.0%) respondents had downloaded and kept the app, but more than a third (35.8%, CI:32.8-38.8%) either did not intend to download it or had deleted it. Significantly more BAME respondents had deleted the app (13.9%, CI :11.8-16.0%, vs 7.4%, CI: 5.8-9.0%), and significantly more older adults over 65 years old did not intend to download it (34.6%, CI: 31.7-37.5% vs 25.2% CI: 22.5-27.9%). Reasons for uptake were broadly to help the NHS and other people, especially among older adults, although significantly fewer BAME agreed that they did so to help the NHS. Reported compliance with received notifications to self-isolate was high, but significantly lower than reported intended compliance without received notifications. Only a fifth (19.5%, CI: 17.0-22.0%) understood that the decision to send self-isolation notifications is automated by the app. There were a range of significantly more negative views among BAME participants, including lower trust in the NHS, whilst older adults were often significantly more positive. Respondents without the app reported significantly lower trust and more negative views towards the app and were less likely to report they understood how the app works.
Conclusions: Whilst compliance of the ~50% who have the app is fairly high, there are issues surrounding trust and understanding that hinder adoption and therefore the effectiveness of digital contact tracing, particularly amongst BAME communities. The study highlights that more needs to be done to improve adoption among groups who are more vulnerable to the effects of the virus to enhance uptake and acceptance of contact tracing apps.

Keywords: Trust; technology adoption; Covid-19; digital contact tracing; coronavirus; vulnerable populations; attitudes; SARS-CoV-2; digital proximity tracing; compliance.

Introduction

Digital contact tracing solutions are employed to monitor and manage the spread of disease during pandemics [1]. Public acceptance of app-based contact tracing in the UK, the EU, and the US is high [2–4], however, to make a difference they must be adopted by a substantial proportion of the population [5,6]. Engaging users in the development, implementation and evaluation of contact tracing can help to maximise engagement and technology acceptance, according to Responsible Research and Innovation frameworks (RRI) [7,8]. This paper therefore reports research to understand the drivers and barriers to adoption of the COVID-19 contact tracing app in the UK, to help increase the effectiveness of such systems and inform future design.

An earlier study of (hypothetical) digital contact tracing in the UK suggested that people would adopt it to protect family and friends, the community, and to stop the pandemic, whilst potential barriers were reported risks of post-pandemic surveillance, increasing anxiety, and fear of hacking [2,4]. The Technology Acceptance Model was used to show that they intention to use a contact tracing app was determined by how useful it was perceived to be; the study also showed that concern about privacy would be overridden by concerns about health [9]. Similarly a study in Germany looked at the difference between the perceived utility of a contact tracing app and a data donation app. Motivations for using and accepting a contact tracing app were higher, and the data donation app was perceived as having less utility for the user [10]. However, there may also be wider social implications (such as having no choice but to download the app for work or venue check-ins) and real-world uptake might differ from usage within a trial.

Trust may also significantly impact the adoption of contact tracing apps, [11], for example a study conducted in Switzerland suggested that higher levels of trust in government and health authorities may also lead to increased uptake [12]; perceived effectiveness of a contact tracing app and the overall app user experience depended on the app being embedded within the health system. In the UK context, this may mean that trust or confidence in the NHS might influence peoples' attitudes towards and usage of the app. In Germany, it was also shown that general trust in official app providers, as well as social trust played an important role, highlighting the importance of both data securing issues and interpersonal solidarity [10]. A study across five countries (France, Germany, Italy, UK and USA) also found that a lack of trust was one of the main barriers for adoption of a hypothetical contact tracing app [4].

Security and privacy have also been shown to be important. In the Netherlands, a study designed to determine the potential uptake of a contact tracing app in the Dutch population showed an adoption rate as high as 64% for apps that were higher on security and privacy-respecting features [13]. In Ireland, there was a shown to be a high level of willingness to download a public health-backed app to augment contact tracing, with 54% of respondents definitely willing to download an app and 30% who would consider downloading it [14]. The most common reason to download the app was linked to social altruism: helping family and friends and a sense of responsibility to the wide community. The most common reason not to download the app was linked to issues of trust, privacy and data security, and fear that technology companies or the government might use the app technology for greater surveillance after the pandemic. Another study across five countries (France, Germany, Italy, UK and USA) found that there was strong support for an app whether it was subject to voluntary or automatic installation, but also identified once more concerns about cybersecurity and privacy [4]. In Australia, 37.3% of participants in a study of 1500 citizens had downloaded the COVIDSafe app, and 27.7% refused to do so [15]. Reasons for not downloading the app included privacy and technical concerns, the belief that that app was unnecessary due to social distancing, distrust in the government, and apathy. This study also highlighted the importance of public health messages for increasing the acceptability of apps and their correct use, whilst also addressing concerns around privacy, data storage, and technical ability needed to operate the app; it also emphasized the importance of identifying and understanding specific barriers to the use of contact tracing apps to improve their design.

Data suggests that specific groups of the population are more at risk of dying of COVID-19, including older adults [16–18] as well as those in Black, Asian or Minority Ethnic (BAME) communities [19,20]. The main challenge among the Dutch population was to increase the uptake among older adults, who were least inclined to install and use a Covid-19 contact tracing app [13]. In

line with this, in Germany age was negatively related to the motivation for using a data donation app [10]. The risk for BAME communities particularly has been linked to socioeconomic factors [21,22]. Furthermore, recent studies have shown increased COVID-19 vaccine hesitancy in certain BAME communities [23–25], however, little is known whether hesitancy also extends to attitudes towards digital contact tracing.

At the time the study reported in this paper closed, 21st December 2020, 2,183,506 people in the UK had tested positive for Covid-19, approximately 3.2% of the population [26]. The UK government released the NHS Covid-19 app on 24th September 2020. The app is entirely automated and decentralized, and relies on Bluetooth proximity as well as self-reporting of symptoms and test results [27,28]. The app has been downloaded more than 21milllion times, suggesting a 56% uptake among the population aged 16 plus who own a smartphone [29,30]. A recent study also showed that the app has been effective in reducing the number of positive cases of Covid-19 in the UK; 1.7 million users were contact-traced by the app, with an estimated reduction to the second wave of Covid-19 by a quarter. However, only 28% of people had actively used the app in the period leading up to the current study [31]. Little is known about views driving or hindering adoption of the app; our research addresses this gap. The study surveys public trust in and adoption of digital contact tracing in the UK, in terms of reported reasons, compliance, and understanding of the app, and especially highlighting significant differences for vulnerable groups.

Methods

Recruitment

Ethical approval was granted for the study by the Research Ethics Committee of the authors' institution. The recruitment was carried out by Ipsos MORI, via email to a nationally representative sample, based on age, gender, and region, drawn from a randomly selected pool of participants who met the relevant criteria. There was also a 10-15% quota on BAME respondents with the same process applied to ensure hitting the minimum required quota. As fieldwork progresses, they specifically target any quota groups that may still be required to meet the final profile that is needed, again randomly selecting within those groups. Participants were incentivized for survey participation through monetary compensation paid into their panel account. As a market research agency Ipsos MORI operate under the MRS code of conduct and are GDPR compliant, so participants privacy is guaranteed. Data is only received via their survey platform in an anonymized form so no personally identifiable information on the participants is received. A total of 2,575 invitations to take part in the study were sent out.

A representative sample of the 1,001 members of the UK population aged 16 to 75 years old took part, weighted to the known offline proportions for age within gender, region, working status, and ethnicity. Participants were asked a series of demographic questions, the full details of which are provided in the Appendix Table A1. A summary of the main self-reported characteristics is provided in Table 1.

Table 1. Summary characteristics of participants

	Summary categories	**%**	**Freq**
Age	Under 65	87.4	874
	65 and over	12.7	127

Gender	Male	50.0	501
	Female	50.0	500
Employment status	Working	66.5	666
	Not working	33.5	335
Education	Up to GSCE	30.7	307
	Post-GSCE	69.4	694
Ethnicity	White	87.5	876
	BAME	11.5	115
	Not stated	1.0	10
Country of residence	England	84.7	847
	Wales	4.8	48
	Scotland	8.5	85
	Northern Ireland	2.1	21

Materials and Procedure

An online survey was carried out between 11th and 21st December 2020, when the UK was between "lockdown 2" and "lockdown 3" and subject to a regional tier system. Questionnaire development was carried out in several stages. First, in the Summer of 2020 a series of interviews were carried out with members of the public with regards to their opinions of, and intention to use, the UK test and trace app when it would be released (paper forthcoming). From these interviews a series of themes were identified, which led to the survey being based on the Technology Acceptance Model (TAM2) [32]. TAM2 identifies several key factors in the adoption of new technology and has been applied to explore acceptance of various technologies including hypothetical COVID-19 tracing apps [9]. The conceptual model is extended with Trust as a factor for acceptance, as it may significantly impact the adoption of contact tracing apps [11]. A list of pertinent questions were developed within the author team and tested and refined involving experts in questionnaire development from Ipsos MORI. Figure 1 illustrates how these questions relate to, and extend, the TAM2 framework.

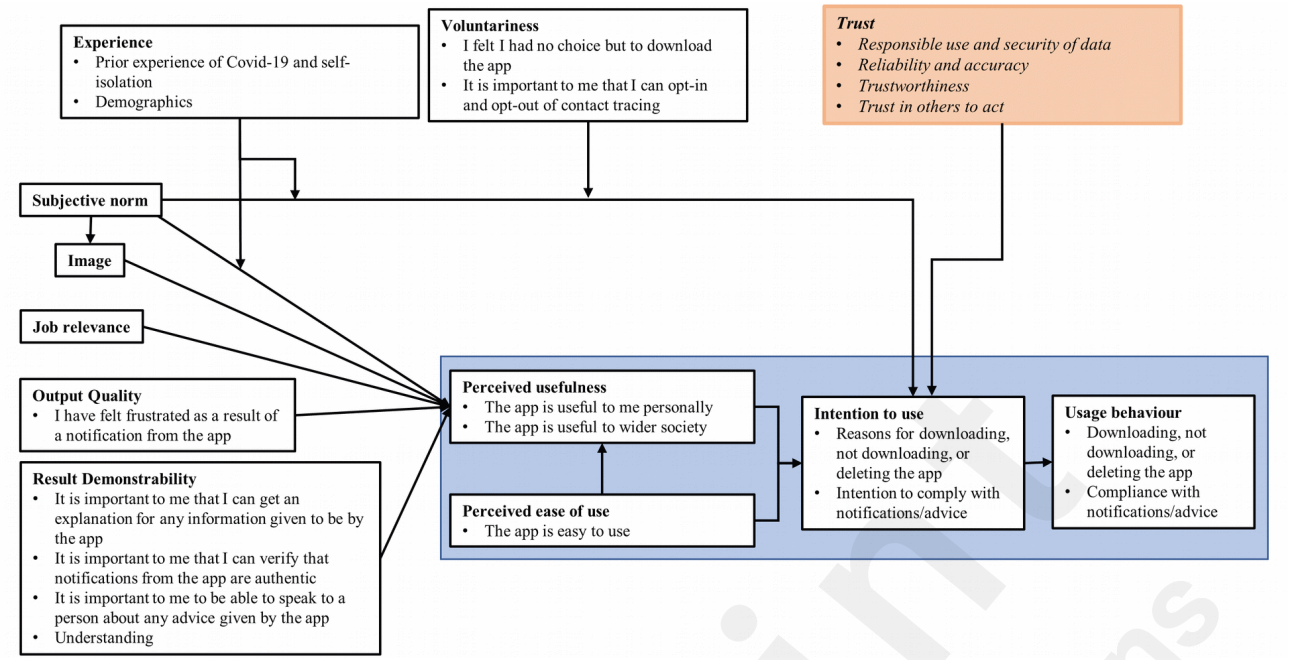

Figure 1 Technology Acceptance Model (TAM2) and its relation to the current questionnaire study. Text in bold in white boxes are existing factors in TAM2 *[32]*, followed by in bullet points examples from the questionnaire. Trust is added as an additional factor (peach-coloured box) affecting intention to use, also including examples from the questionnaire.

Recruitment and data collection was carried out by Ipsos MORI who also carried out piloting of the questionnaire. The questionnaire had an initial data review on day one with n=61 and thoroughly checked to make sure that all data is being collected correctly (for example checking routing and displaying of correct answer options), as well as checking for anomalies and understanding. The data was reviewed again at n=213 to ensure data quality.

Participants were provided with information and privacy notices and gave informed consent to take part. All questions were closed-ended, either multiple choice or rated on Likert or Likert-like scales from 1 to 5 (“strongly disagree” to “strongly agree”, or “not at all” to “entirely” as relevant), plus a single open-ended question for further comments; participants were routed to appropriate questions based on previous answers.

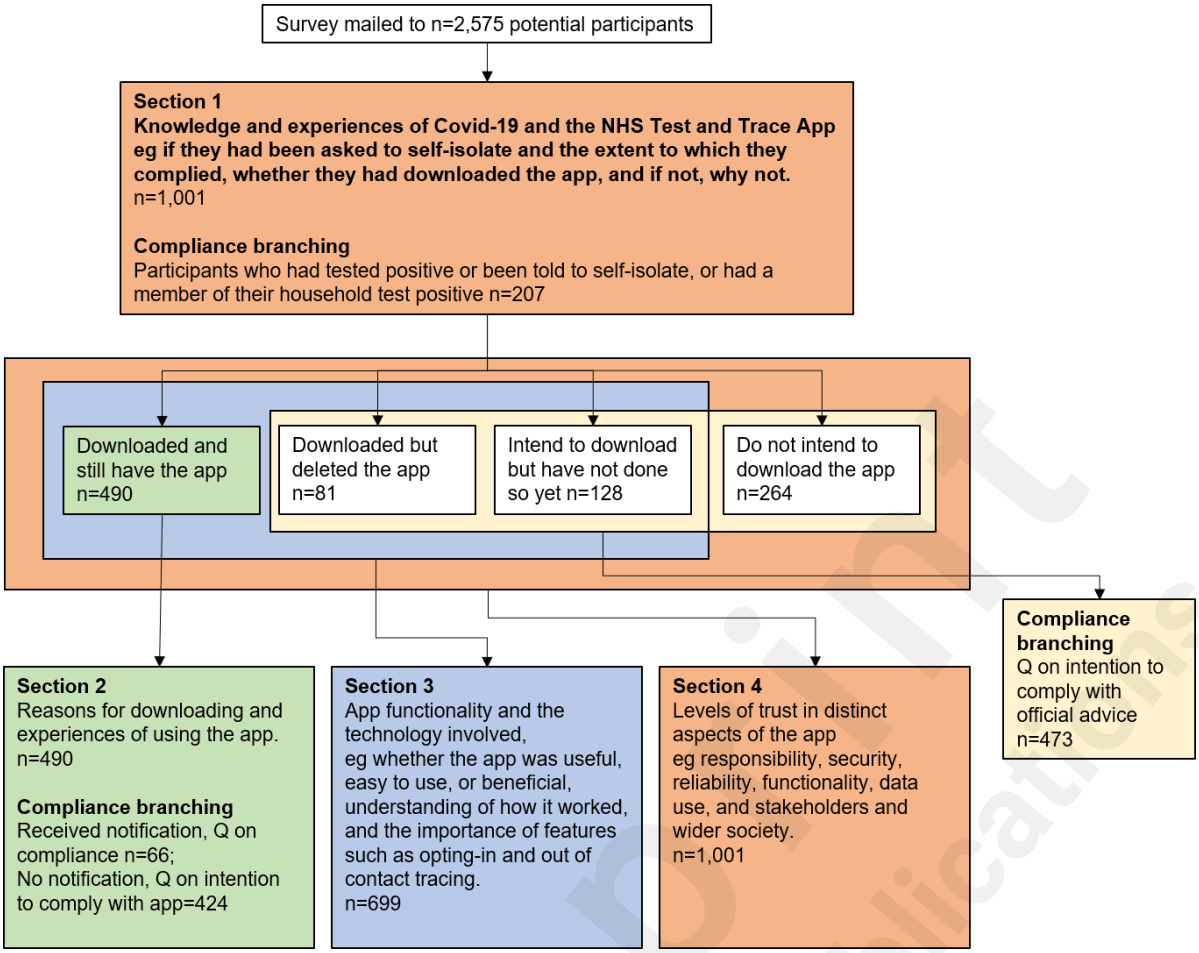

Figure 2 Illustration of major sections of the survey and subgroups identified for branching.

Figure 2 shows the survey flow and resulting major subpopulations that were used for branching. Section 1 of the survey asked participants to indicate what knowledge and experiences they had of Covid-19 and the NHS Test and Trace App, for example if they had been asked to self-isolate and the extent to which they complied, whether they had downloaded the app, and if not, why not. Section 2 focused on those with the app and collected reasons for downloading and experiences of using the app. Section 3 asked about app functionality and the technology involved, including whether the app was useful, easy to use, or beneficial, understanding of how it worked, and the importance of features such as opting-in and out of contact tracing. Section 4 asked about levels of trust in distinct aspects of the app including responsibility, security, reliability, functionality, data use, and stakeholders and wider society.

Statistical Analysis

Responses were analysed using IBM SPSS statistics 26 and Excel. Summary statistics (mean, median, standard deviation, interquartile range) or frequencies were extracted for all questions. Confidence intervals for proportions are given at the 95% level. Most questions were significantly non-normal as shown by skewness and kurtosis, so non-parametric tests are appropriate. In the text, $\acute{x}$ indicates the sample mean, given with statistical test results, whilst $\tilde{x}$ indicates the median response on a Likert-like scale. All inferential statistical analysis was carried out with $p<0.05$ as the threshold for statistical significance. Missing data was reported as ‘no response’ and included in frequency calculations; missing data for inferential statistical analysis and the calculation of means was excluded.

Sub-group analyses using Independent-Samples Mann Whitney U or Chi-Squared were used to

compare those who had been told to self-isolate with those who had not, white participants were compared with BAME participants, and under 65 year-olds with 65 year-olds and over. Independent-Samples Kruskal Wallis tests were used to compare those who had the app, did not have the app, had deleted the app, or intended to download the app but had not yet done so. Post-hoc tests were carried out to identify between which groups differences were significant, with Bonferroni corrections to account for multiple testing. Due to using the non-parametric versions of inferential statistics, and because the weighted values for the data all rounded to 1, weighting was not used. However, exploratory analysis revealed no difference in significance when using the parametric versions of tests.

Results

Adoption of the Test and Trace App

A total of 1,001 participants took part in the study. Most participants (96.2%, n=963, CI: 95.0-97.4%) had heard of the NHS Covid-19 mobile phone app, of which 50.9% (n=490, CI:47.8-54.0%) had downloaded the app and still had it on their phone. A further 13.3% (n=128, CI:11.2-15.4%) had not yet downloaded it but intended to, 27.4% (n=264, CI:24.6-30.2%) did not intend to download it, and 8.4% (n=81, CI:6.7-10.1%) had downloaded it but since deleted it.

Among the 27.4%(n=264) who did not intend to download it, the most common reasons (Table 2) were a desire not to be tracked, not thinking it would be effective, not wanting to take part in contact tracing in that way, and lack of trust in those who built the app. Of the 8.4% (n=81) who had decided to delete the app, this was mostly because they did not think it was effective or did not want to be tracked. Reasons for the 13.3% (n=128) who intended to download the app were mostly to help the NHS or to help protect their friends and family or themselves, as well as to reduce the spread of the virus and to help protect broader society (Table 3).

Table 2. Reasons for not having the Test and Trace app for those who do not intend to download it (n=264) and those who downloaded but deleted the app (n=81)
Multiple answers were allowed. 95% Confidence intervals are given in brackets.

	Reasons for not downloading (n=264)		**Reasons for deletion (n=81)**	
	% (CI)	**Freq.**	**% (CI)**	**Freq.**
I don't want to be tracked	39.8 (36.8-42.8)	105	27.2 (24.4-30.0)	22
I don't think it will be effective	30.3 (27.5-33.1)	80	34.6 (31.7-37.5)	28
I choose/chose not to take part in contact tracing in this way	29.5 (26.7-32.3)	78	14.8 (12.6-17.0)	12
I don't trust the people who built the app	27.3 (24.5-30.1)	72	17.3 (15.0-19.6)	14
The app doesn't/didn’t work on my mobile phone	10.6 (8.7-12.5)	28	17.3 (15.0-19.6)	14
I don't have a smart phone	10.2 (8.3-12.1)	27	N/A	
I don't want to be told to self-isolate	6.1 (4.9-7.6)	16	11.1 (9.2-13.0)	9
None of the above	9.5 (7.7-11.3)	25	8.6 (6.9-10.3)	7

I wouldn't/didn’t know how to use it	4.5 (3.2-5.8)	12	14.8 (12.6-17.0)	12
Don’t know	0.1 (0-0.3%)	1	0.0	0

Of the 50.9% (n=490) who had downloaded the app, 92.0% (n=451, CI:90.3-93.7%) had opened the app and had a look around, 66.7% (n=327, CI:63.8-69.6%) had used it for a venue check-in, 58.4% (n=286, CI: 55.3-61.5%) had made use of the ‘check symptoms’ section; 71.2% (n=349, CI: 68.4-74.0%) had contact tracing always switched on, 20.4% (n=100, CI:17.9-22.9%) sometimes, and 1.8% (n=9, CI:1.0-2.6%) never turned it on, but 6.5% (n=32, CI: 5.0-8.0%) did not know if contact tracing was enabled or not. The strongest reasons given for downloading the app were helping the NHS and protecting friends and family (Table 3).

Table 3. Reasons for intention to download (n=128) and for downloading (n=490) the NHS Covid-19 App**.** Participants who intended to download were asked to select all reasons which applied, whilst those who had the app were asked to what extent each reason was true. 95% Confidence intervals are given in brackets.

	Indicated as reason for intention to download (n=128)		**Extent to which reason was a motivation for downloading app (n=490)**	
	% (CI)	**Freq**	**Median (IQR)**	**Mean (SD)**
To help the NHS	65.6 (62.7-68.5)	84	5 (1)	4.42 (0.753)
To help protect my friends and family	62.5 (59.5-65.5)	80	5 (1)	4.36 (0.792)
To help protect myself	54.7 (51.6-57.8)	70	4 (1)	4.27 (0.883)
Because it will reduce the spread of the virus	43.0 (39.9-46.1)	55	4 (1)	4.11 (0.966)
To help protect broader society	35.9 (32.9-46.1)	46	4 (1)	4.2 (0.897)
Because I need it to check into venues	18.8 (16.4-21.2)	24	4 (1)	3.54 (1.179)
Because the government told me to	11.7 (9.7-13.7)	15	4 (1)	3.46 (1.177)
Because everyone else is	9.4 (7.6-11.2)	12	3 (2)	3.14 (1.177)
Because it is a requirement for my job	5.5 (4.1-6.9)	7	2 (3)	2.53 (1.361)
None of the above	1.6 (0.8-2.4)	2	N/A	N/A

Compliance with Official Advice and Self-Isolation

Nearly half (43.4%, n=434, CI: 40.3-46.5%) had at least one of the following experiences: 4.0% (n=40, CI:2.8-5.2%) had tested positive for Covid-19, 14.1% (n=141, CI: 11.9-16.3%) had a member of their household test positive, 27.9% (n=279, CI:25.1-30.7%) had another person close to them test positive, and 8.5% (n=85, CI:6.8-10.2%) had been asked to self-isolate (in any form, whether via app or other means). Participants who had themselves or a member of their household been affected, or

asked to self-isolate (n=207) were asked to indicate how much they had complied with any official advice they received, regardless of through the app or another source; average response across all four experiences was 'very much' ($\bar{x}$=3.88). However, ten percent (9.7%, n=22, CI:7.9-11.5%) stated they did not receive any official advice at all, most often when a non-family member of their household had tested positive (13.8%, n=12, CI: 11.7-15.9%) (Figure 3). Note that this implies that some participants therefore did not consider being asked to self-isolate as 'official advice'.

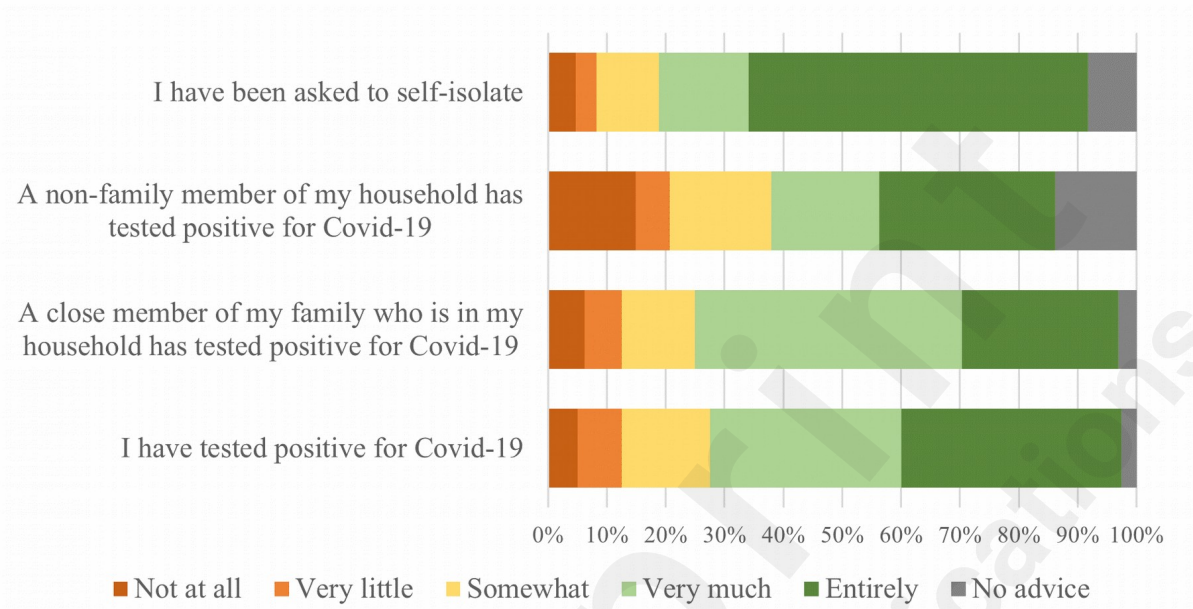

Figure 3 Compliance with official advice, dependent on the circumstances. Participants were asked 'To what extent, if at all, did you follow any advice given to you?'

Of the 47.3% (n=473) of participants who did not currently have the app, most stated they would either very much or entirely follow advice to self-isolate if they received a call (74.4%, n=352, CI=71.7-77.1%). Of participants with the app (50.9%, n=490), 13.5% (n=66, CI=11.4-15.6%) had been notified to self-isolate and 45.5% (n=30, CI: 42.4-48.6%) of those said that they had entirely followed the recommendation, whilst of the 85.3% (n=418, CI: 83.1-87.5%) who stated that they had not been notified by the app to self-isolate, 70.6% (n=299, CI:73.4-78.6%) said they would entirely follow a recommendation from the app if they received one (Figure 4). An independent-Samples Mann Whitney U test comparing those who had received advice to self-isolate (n=66) from the app to those who had not (n=418) shows that reported intention to comply with advice is significantly stronger than reported actual compliance ($\bar{x}_{intention}$=4.59, $\bar{x}_{actual}$=4.06, U=17673.0, P<.001).

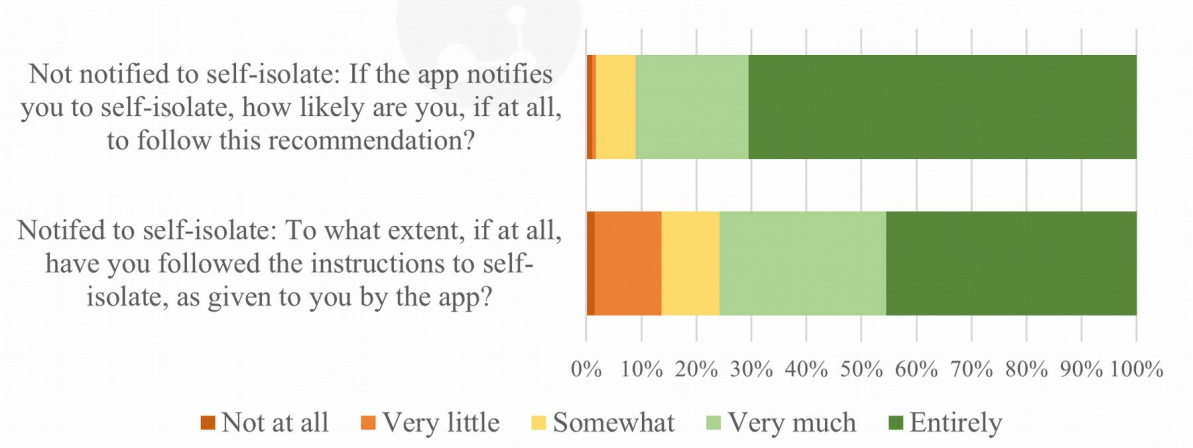

Figure 4 Compliance and intention to comply with app notifications to self-isolate. *An independent-Samples Mann Whitney U test*

comparing those who had received advice to self-isolate (n=66) from the app to those who had not (n=418) shows that reported intention to comply with advice is significantly stronger than reported actual compliance ($\bar{\chi}_{intention}$=4.59, $\bar{\chi}_{actual}$=4.06, U=17673.0, p<.001).

Understanding and attitudes towards the app

Of participants who currently have the app, have deleted it, or intended to download it (n=699), most stated that they thought that decisions to send a notification to self-isolate were made by both humans and the app (54.2%, n=379, CI: 51.1-57.3%); only 19.5% (n=136, CI: 17.0-22.0%) thought they were made by the app only. Participants with the app agreed that they knew how the app worked, that it was easy to use, useful to them and to wider society, that the regulations surrounding the app were sufficient, and that it was important that they could get explanations and verify information from the app, that they could speak to a person about any advice they receive and have the option to opt-out of contact tracing if they chose to. They were neutral about data concerns and about whether they had a choice in downloading the app. They tended to disagree that they had been frustrated by a notification from the app. Independent-Samples Kruskall Wallis tests showed that participants who had deleted the app (n=81) felt significantly less than those who still have the app (n=490) that they understood the app ($X^2(2)=16.085$, $P=.003$), that it was useful to them ($X^2(2)=26.190$, $P<.001$) or wider society ($X^2(2)=29.729$, $P<.001$), that regulations were sufficient ($X^2(2)=12.856$, p=0.0031), or that it was easy to use ($X^2(1)=41.182$, $P<.001$). It is also significantly less important to them that they can verify app notifications ($X^2(2)=18.294$, $P<.001$). However, they showed significantly more concern about how their data is used ($X^2(2)=25.669$, $P<.001$) and were more likely to have been frustrated by a notification from the app ($X^2(1)=18.294$, $P<.001$). None of the other statements (Table 4) were significantly different.

Table 4. Levels of agreement with statements related to the technology and ecosystem surrounding the NHS Covid-19 app, for participants who still have the app (n=490) and participants who deleted the app (n=81).
Statements are rated on a scale from 1=strongly disagree to 5=strongly agree.
Independent-Samples Kruskall Wallis tests were carried out with a significance level of $P<.05$ and post-hoc tests to indicate between which groups the differences were significant, with Bonferroni correction to account for multiple tests. Additional differences including those that downloaded and still have the app and those that intend to download the app are in the Appendix Table A2.

	Still have the app (n=490)		**Deleted the app (n=81)**		
	Median (IQR)	**Mean (SD)**	**Median (IQR)**	**Mean (SD)**	***P*-value**
I understand how the NHS Covid-19 app works	4 (1)	3.99 (0.850)	4 (1)	3.57 (1.036)	.003
I am concerned about how my data will be used by the app	3 (2)	3.04 (1.250)	4 (1)	3.73 (1.037)	<.001
The app is useful to me personally	4 (2)	3.84 (0.944)	3 (2)	3.19 (1.174)	<.001
The app is useful to wider society	4 (1)	4.11 (0.874)	4 (1)	3.47 (1.096)	<.001
It is important to me that I can get an explanation for any information given to me by the app	4 (1)	4.01 (0.801)	4 (2)	3.72 (1.028)	.052
It is important to me that I can	4 (1)	4.14	4 (1)	3.60	<.001

verify that notifications from the app are authentic		(0.823)		(1.137)	
The regulations governing the creation of the app are sufficient	4 (1)	3.72 (0.934)	3 (1)	3.37 (1.089)	.003
It is important to me to be able to speak to a person about any advice given by app	4 (1)	3.71 (0.982)	4 (1)	3.64 (1.099)	1.000
It is important to me that I can opt-in and opt-out of contact tracing	4 (1)	3.50 (1.166)	4 (1)	3.58 (0.947)	1.000
The app is easy to use	4 (1)	4.18 (0.815)	4 (1)	3.42 (1.082)	<.001
I felt that I had no choice but to download the app	3 (2)	2.98 (1.273)	3 (2)	3.27 (1.162)	0.057
I have felt frustrated as a result of a notification from the app	2 (2)	2.59 (1.279)	3 (2)	3.28 (1.154)	<.001

Trust in Test and Trace

Whilst those who still have the app (n=490) tended to agree that they had trust in various aspects of the app (Table 5), Independent-Samples Kruskall Wallis tests showed that those who chose not to download the app (n=264) had significantly less trust, feeling neutral that they trusted that the data is used responsibly ($X^2(3)=222.17$, $P<.001$), stored securely ($X^2(3)=236.282$, $p<.001$), that the app does what it's supposed to do ($X^2(3)=273.932$, $p<.001$), and is basically trustworthy ($X^2(3)=243.144$, $p<.001$). They were also significantly less trusting of others, feeling neutral about whether they trusted others to download the app ($X^2(3)= 128.751$, $P<.001$) or to self-isolate if they were told to ($X^2(3)=74.064$, $P<.001$). Participants who chose not to download the app were also significantly more likely not to trust that their data will be deleted when the app says it will ($X^2(3)=251.149$, $P<.001$), or that the app is reliable ($X^2(3)=277.74$, $P<.001$). Trust was thought to be important for all participants to feel comfortable using the app, although significantly less so for those who chose not to download it ($X^2(3)=23.953$, $P<.001$).

Table 5. Levels of agreement with statements related to trust in the NHS Covid-19 app, for participants who have the app (n=490) and participants who do not intend to download the app (n=264).
Statements are rated on a scale from 1=strongly disagree to 5=strongly agree.
Independent-Samples Kruskall Wallis tests were carried out with a significance level of $P<.05$ and post-hoc tests to indicate between which groups the differences were significant, with Bonferroni correction to account for multiple tests. Additional differences including those that deleted or intended to download the app are in the Appendix Table A3.

	Have the app (n=490)		**Do not intend to download the app (n=264)**		
	Median (IQR)	**Mean (SD)**	**Median (IQR)**	**Mean (SD)**	***P*-value**
I trust that the data collected by app is used responsibly	4 (1)	3.98 (0.888)	3 (2)	2.63 (1.224)	<.001
I trust that the data collected by the app is stored securely	4 (2)	3.93 (0.916)	3 (1)	2.56 (1.149)	<.001
I feel that the app is reliable	4 (2)	3.89	2 (1)	2.42	<.001

		(0.919)		(1.062)	
I trust that the app will do what it is supposed to do	4 (1)	3.97 (0.880)	3 (1)	2.53 (1.136)	<.001
I think the NHS Covid-19 app is basically trustworthy	4 (1)	4.03 (0.875)	3 (1)	2.73 (1.129)	<.001
I think that most other people will download the app	4 (1)	3.58 (1.026)	3 (1)	2.65 (1.086)	<.001
I trust that most other people will self-isolate if told to do so by the app	4 (1)	3.54 (1.113)	3 (2)	2.80 (1.106)	<.001
I trust that my data will be deleted when the app says it will	4 (2)	3.93 (0.892)	2 (2)	2.48 (1.196)	<.001
It is important to me that I trust the app in order to use it	4 (1)	4.15 (0.736)	4 (2)	3.86 (1.145)	<.001

Whilst those who still had the app (n=490) agreed that they trusted most of the stakeholders involved in the Test and Trace system (Table 6), Independent-Samples Kruskall Wallis tests showed that those who chose not to download the app (n=264) were significantly more neutral about big tech companies ($X^2(3)=82.127$, $P<.001$), small hospitality venues ¿$X^2(3)=34.789$, p<.001), large hospitality venues ($X^2(3)=56.079$, $P<.001$), and their local council ($X^2(3)=61.732$, $P<.001$), and significantly more negative about their trust in the UK government ($X^2(3)=61.732$, $P<.001$). Those with the app were neutral about their trust in private contractors, whilst those without were significantly more negative ($X^2(3)=85.580$, $P<.001$). Finally, both groups tended to agree that they trusted the NHS, but those without the app significantly less so ($X^2(3)=78.899$, $P<.001$).

Table 6. Levels of trust in stakeholders involved in the Test and Trace system in participants who still have the app (n=490) and participants who do not intend to download the app (n=264).
Statements are rated on a scale from 1=strongly disagree to 5=strongly agree.
Independent-Samples Kruskall Wallis tests were carried out with a significance level of $P<.05$ and post-hoc tests to indicate between which groups the differences were significant, with Bonferroni correction to account for multiple tests. Additional differences including those that deleted or intended to download the app are in the Appendix Table A4.

	Have the app (n=490)		**Do not intend to download the app (n=264)**		
	Median (IQR)	**Mean (SD)**	**Median (IQR)**	**Mean (SD)**	***P*-value**
I trust…					
The big tech companies, such as Google and Apple	4 (1)	3.42 (0.996)	3 (1)	2.65 (1.134)	<.001
Private contractors, such as Serco	3 (2)	3.07 (1.086)	2 (2)	2.29 (1.021)	<.001
Small hospitality venues, such as independent pubs and cafes	4 (1)	3.62 (0.864)	3 (2)	3.13 (1.125)	<.001
Larger hospitality venues, such as chain restaurants	4 (1)	3.52 (0.923)	3 (2)	2.91 (1.068)	<.001
The UK Government	4 (2)	3.32 (1.213)	2 (2)	2.39 (1.181)	<.001
My local council	4 (1)	3.51 (0.968)	3 (2)	2.86 (1.096)	<.001
The NHS	4 (1)	4.33	4 (2)	3.72 (1.102)	<.001

		(0.774)			

Vulnerable Groups

Of the 11.5% (n=115) of participants who identified as BAME, 53.0% (n=61, CI: 49.9-56.1%) had any close experience of Covid-19, including friends and family receiving diagnoses, compared to 42.3% (n=371, CI: 39.2-45.4%) of white participants (Table 7). Chi-Squared tests showed that significantly more BAME participants had a member of their household test positive, ($X^2(1)=10.00$, $P<.05$); whilst more BAME participants had tested positive or had another person close to them test positive than white participants, the differences were not significant; a similar proportion had been asked to self-isolate. Significantly fewer BAME participants than white participants had downloaded the app ($X^2(1)=4.71$, $P<.05$) and more had deleted the app ($X^2(1)=4.51$, $P<.05$); whilst fewer BAME participants did not intend to download it and more intended to download it, neither difference was significant. BAME participants agreed significantly less that they downloaded the app to help the NHS ($\bar{x}_{BAME}=4.02$, $\bar{x}_{white}=4.46$, U=7803.5, $P=.001$), and significantly more that it was a requirement for their job ($\bar{x}_{BAME}=3.19$, $\bar{x}_{white}=2.45$, U=13734.0, $P<.001$); no other reasons showed a difference.

Table 7. Experiences of Covid-19 among vulnerable populations (BAME (n=115) and 65 year-olds and over (n=127)) compared to other participants (white n=876, 65 year-olds and over n=874). 95% Confidence intervals are given in brackets.

	White		**BAME**		**Under 65**		**65 and over**	
	% (CI)	**Freq**	**% (CI)**	**Freq**	**% (CI)**	**Freq**	**% (CI)**	**Freq**
Any close experience of Covid-19	42.3 (39.2-45.4)	371	53.0 (49.9-56.1)	61	46.6 (43.5-49.7)	407	22.0 (19.4-24.6)	28
Tested positive	3.7 (2.5-4.9)	32	7.0 (5.4-8.6)	8	4.5 (3.2-5.8)	39	0.9 (0.3-1.5)	1
Member of household tested positive	12.7 (10.6-14.8)	112	25.2 (22.5-27.9)	29	15.6 (13.4-17.8)	136	3.9 (2.7-5.1)	5
Another close person tested positive	27.5 (24.7-30.3)	241	31.3 (28.4-34.2)	36	30.3 (27.5-33.1)	265	11.0 (9.1-12.9)	14
Asked to self-isolate	8.7 (7.0-10.4)	76	7.0 (5.4-8.6)	7	8.5 (6.8-10.2)	74	8.8 (7.0-10.4)	11

Table 8. Downloads of NHS Covid-19 App among vulnerable populations (BAME (n=115) and 65 year-olds and over (n=127)) compared to other participants (white n=876, under 65 year-olds n=874). 95% Confidence intervals are given in brackets.

	White		**BAME**		**Under 65**		**65 and over**	
	%	**Freq**	**%**	**Freq**	**%**	**Freq**	**%**	**Freq**
Downloaded	50.2 (47.1-53.3)	440	41.7 (38.6-44.8)	48	48.5 (45.4-51.6)	424	52.0 (48.9-55.1)	66
Downloaded then deleted	7.4 (5.8-9.0)	65	13.9 (11.8-16.0)	16	9.0 (7.2-10.8)	79	1.6 (0.8-2.4)	2
Not downloaded	12.0	105	16.5	19	13.2	115	10.2	13

but intend to	(10.0-14.0)		(14.2-18.8)		(11.1-15.3)		(8.3-12.1)	
Do not intend to download	26.9 (24.2-29.6)	236	20.9 (18.4-23.4)	24	25.2 (22.5-27.9)	220	35.6 (32.6-38.6)	44

Of the 12.7% (n=127) of participants who were 65 years of age or over, only 22.0% (n=28, CI: 19.4-24.6%) had any close experience of Covid-19 compared to 46.6% (n=407, 43.5-49.7%) of the under 65 year-olds. Chi-Squared tests showed that significantly more of the under 65s than over 65s had a member of their household test positive ($X^2(1)=10.37$, $P<.05$), or another person close to them ($X^2(1)=4.72$, $P<.05$), with no significant difference in testing positive for Covid-19, or being asked to self-isolate. Significantly more over 65s had downloaded the app ($X^2(1)=7.03$, $P<.05$), fewer over 65s had deleted it ($X^2(1)=8.15$, $P<.05$) but significantly more over 65s than under 65s did not intend to download the app ($X^2(1)=13.52$, $P<.05$); similar proportions intended to download the app. Over 65s agreed significantly more that they downloaded the app to help the NHS ($\dot{x}_{>65}=4.59$, $\dot{x}_{<65}=4.39$, U=16164.0, $P=.022$), to help protect their friends and family ($\dot{x}_{>65}=4.50$, $\dot{x}_{<65}=4.34$, U=16220.0, $P=.021$) or broader society ($\dot{x}_{>65}=4.45$, $\dot{x}_{<65}=4.16$, U=16630.5, $P=.008$) but less likely to agree that it was needed for them to check into venues ($\dot{x}_{>65}=3.15$, $\dot{x}_{<65}=3.60$, U=11089.5, $P=.005$) or for their job ($\dot{x}_{>65}=1.94$, $\dot{x}_{<65}=2.63$, U=9874.0, $P<.001$); no other reasons showed a difference.

Of those that do not have the app, intention to comply with a phone call asking them to self-isolate was the same between both BAME and white groups ($\dot{x}_{BAME}=3.93$, $\dot{x}_{white}=4.14$, U=13909.0, $P=.057$, NS) and over 65s and under 65s groups ($\dot{x}_{>65}=4.39$, $\dot{x}_{<65}=4.08$, U=10573.0, $P=.109$, NS). Of those with the app who had been notified to self-isolate, there was no significant difference in compliance between populations ($\dot{x}_{BAME}=3.67$, $\dot{x}_{white}=4.18$, U=291.5, $P=.137$; $\dot{x}_{>65}=4.25$, $\dot{x}_{<65}=4.05$, U=150.0, $P=.508$, NS), but of those that had not been notified, white participants reported a significantly higher intention to comply ($\dot{x}_{BAME}=4.26$, $\dot{x}_{white}=4.63$, U=4544.5, $P=.006$), as did the over 65s ($\dot{x}_{>65}=4.90$, $\dot{x}_{<65}=4.54$, U=13838.5, $P<.001$).

BAME participants had significantly lower understanding of how decisions were made by the app ($X^2(2)=9.24$, $P<.05$) (Table 9); more thought it was either humans only or humans and the app, whilst far fewer understood that it was the app only. Whilst more over 65s than under 65s also felt that decisions were made entirely by humans, fewer felt it was by both humans and the app, and more correctly identified that decisions were made entirely by the app; there is no significant difference between the age groups (Table 9).

Table 9. Beliefs about how decisions are made by the NHS Covid-19 app among vulnerable populations (BAME (n=115) and 65 year-olds and over (n=127)) compared to other participants (white n=876, under 65 year-olds n=874). 95% Confidence intervals are given in brackets.

	White		**BAME**		**Under 65**		**65 and over**	
	%	**Freq**	**%**	**Freq**	**%**	**Freq**	**%**	**Freq**
Humans only	17.8 (15.4-20.2)	156	22.6 (20.0-25.2)	26	18.2 (15.8-20.6)	159	19.7 (17.2-22.2)	25
Both humans and the app	37.0 (34.0-40.0)	324	44.3 (41.2-47.4)	51	39.2 (36.2-42.2)	343	28.3 (25.5-31.1)	36
App only	14.8	130	5.2	6	13.3	116	15.7	20

	(12.6-17.0)		(3.8-6.6)		(11.2-15.4)		(13.4-18.0)	

BAME participants were more concerned about how their data will be used ($\bar{x}_{white}$=3.07, $\bar{x}_{BAME}$=3.58, U=31052.5, *P*=.001), felt more strongly that they had no choice but to download the app ($\bar{x}_{white}$=2.95, $\bar{x}_{BAME}$=3.59, U=20857.0, *P*<.001) and that they had felt frustrated as a result of a notification from the app ($\bar{x}_{white}$=2.59, $\bar{x}_{BAME}$=3.42, U=21961.5, *P*<.001). They felt less strongly that the app was easy to use ($\bar{x}_{white}$=4.11, $\bar{x}_{BAME}$=3.75, U=12844.5, *P*=.004) or that it was useful to wider society ($\bar{x}_{white}$=4.05, $\bar{x}_{BAME}$=3.75, U=21371.5, *P*=.013). Over 65s were less concerned about how their data will be used ($\bar{x}_{>65}$=2.72, $\bar{x}_{<65}$=3.20, U=20663.0, *P*=.009), less likely to feel that they had no choice but to download the app ($\bar{x}_{>65}$=2.68, $\bar{x}_{<65}$=3.07, U=14010.0, *P*=.013) or that they had felt frustrated as a result of a notification from the app ($\bar{x}_{>65}$=2.09, $\bar{x}_{<65}$=2.77, U=11854.5, *P*<.001). It was also less important to them that they can opt-in and opt-out of contact tracing ($\bar{x}_{>65}$=3.18, $\bar{x}_{<65}$=3.56, U=19243.0, *P*<.001). There were no other significant differences in attitudes.

BAME participants felt it was less important that they trusted the app ($\bar{x}_{white}$=4.04, $\bar{x}_{BAME}$=3.79, U=43247.5, *P*=.008). They had more trust in the big tech companies ($\bar{x}_{white}$=3.14, $\bar{x}_{BAME}$=3.43, U=57731.5, *P*=.008) and private contractors ($\bar{x}_{white}$=2.78, $\bar{x}_{BAME}$=3.24, U=61597.5, *P*<.001), but less trust in the NHS ($\bar{x}_{white}$=4.12, $\bar{x}_{BAME}$=3.97, U=44705.5, *P*=.035). Conversely, over 65s had less trust in the big tech companies ($\bar{x}_{>65}$=2.97, $\bar{x}_{<65}$=3.21, U=49432.0, *P*=.038) and private contractors ($\bar{x}_{>65}$=2.53, $\bar{x}_{<65}$=2.88, U=46020.0, *P*=.001), but more trust in the UK government ($\bar{x}_{>65}$=3.24, $\bar{x}_{<65}$=2.97, U=62275.5, *P*=.022). There were no other significant differences in trust.

Discussion

Principal Results and Comparison with Prior Work

Just over half of those surveyed had downloaded the app, agreeing with other estimates for the UK [29]. Reasons for app uptake were predominantly to help the NHS, protect others, and reduce the spread of the virus, broadly agreeing with previous research [2,4]. Older adults had more community-minded and altruistic attitudes, being more likely to download the app to help the NHS, friends, family, and society, but they also had less intention to download the app. However, almost one in nine of those who initially downloaded the app eventually deleted it, especially BAME participants, although a similar number had downloaded and kept the app as white participants. However, this increased deletion is a particular concern as their vulnerability is reflected in that twice as many BAME participants had tested positive or had a household member test positive for COVID-19.

In line with previous studies [4,10,13-15], reasons for not downloading or deleting the app related to not wanting to be tracked, a feeling it would be ineffective, and a lack of trust in the people who built the app. People who decided to delete the app were more likely than those who kept it to feel that it was not useful or easy to use, as expected from TAM2 [32]; they also felt they understood less how it worked, were more concerned about how their data is used, and were more likely to have been frustrated by a notification from the app. This shows how important a trustworthy user experience is for the adoption of contact tracing apps. BAME participants who currently had the app also had higher levels of concern about their data, felt the app was less easy to use and useful to society, and were more likely to have been frustrated by the app; this could lead to them deleting the app in the future. Those involved in the design of contact tracing should pay particular attention to the needs of BAME app users. On the other hand, older adults had less concern about their data, and less frustration. Engaging users in the development, implementation and evaluation of contact tracing can

help to maximise engagement and technology acceptance, according to the Responsible Research and Innovation framework (RRI) [7,8], helping designers to consider wider social implications of a technology and how real-world use might differ from usage within a trial or with a prototype. Working together with users to anticipate concerns, and develop solutions, can be an effective mechanism to achieve the adoption of digital solutions.

Feelings that there was a lack of choice in using the app were stronger among BAME participants, and lowest among older adults; BAME participants were also more likely to state that they had to download it for their job. Participants required a level of control over the app, feeling it was important to get explanations, verify and speak to people about notifications, and to be able to opt-out of contact tracing; interestingly the latter was less important for older adults. Most people stated that they would be or had been highly compliant with advice to self-isolate, although intention was significantly higher than actual reported compliance, especially in older adults. Actual reported compliance was similar across the different groups, although our findings suggest that white people tend to overstate their intention to comply. This finding may be impacted by the reduced trust in the government, previously discussed, and as well as a perceived lack of incentives offered for compliance [33]. It is also interesting that when asked how much they complied with 'official advice', some participants who had been asked to self-isolate (by the app or otherwise)occasionally answered that they had not received any official advice. This implies that the instruction to self-isolate was perceived as being a suggestion rather than holding any authority, which may in turn have led to them not taking the same precautions as they would have if they felt that the instruction to self-isolate was an official request.

Trust in the app is moderate. Participants who did not download the app had significantly lower trust in the app, especially in whether their data would be deleted, and whether the app was reliable. They also had significantly lower trust in other users, and in stakeholders surrounding the app, suggesting that trust is an important consideration in the design of contact tracing applications. Trust in the government is particularly low, and may be a factor in adoption of app-based contact tracing [2,4,34,35], although it was higher among older adults, who were more concerned about big tech and private contractors. The BAME population had more trust in the big tech companies and private contractors, but less trust in the NHS. BAME participants were also significantly less likely to download the app to help the NHS. A recent study on health-related quality of life revealed inequalities within English ethnic minorities [36] including poor primary care experiences, inadequate support from local services and low patient self-confidence. This indicates that government slogans like "protect the NHS" may not have the intended effect on BAME communities and should be rethought to be more inclusive. However, reasons for a lack of trust of BAME people in the governments and institutions in the UK is likely linked to persistent issues of structural racism [37] and thus unlikely to be changed through singular measures alone, such as government messaging.

Finally, although participants felt they understood how the app worked, the results show that most people do not know that decisions about notifications are entirely made by the app [27,29], without human involvement. Understanding was particularly low in BAME communities. This lack of understanding may affect uptake and continued use, as it may negatively impact trust, and consequently the app's popularity, perceived validity and reliability [38]. At the same time, perceived human intervention may falsely increase trust in the app, as a completely automated system is likely to be recognised as having an unfair impact on the population, limiting freedom without taking into consideration personal circumstances [39].

Limitations and Future Work

Whilst the sample was representative of the UK population in terms of age, gender, region, and ethnicity some demographics that were not measured, such as income and political leaning may have affected the results. Additionally, this representativeness means that the sample sizes for the vulnerable populations, although proportionate to population, were small compared to the overall sample. Future work should consider enriching the sample with greater numbers of minority populations in order to capture their views more thoroughly. Additionally whilst the sample was drawn from an online panel, this bias towards the online population was considered acceptable for this study as the focus was on use of a smartphone application – implying internet access. Recent estimates suggest that 92% of adults in the UK are recent internet users, including 54% of those over 75 years of age and 81% of disabled adults; only 6.3% of adults had never used the internet [40]. However, this does mean that potential respondents who do not have access to or the ability to use the internet, as were individuals who were not part of the online panel, were unable to take part in this study. Whilst out of scope for this paper, this should be examined in future as such issues could disproportionately affect vulnerable communities.

Future work should also consider multivariable analyses to account for the demographics of participants, to aid in explaining the differences found between vulnerable subgroups. For example, it is possible that lower trust in the government or the NHS might be driven by factors such as age, gender, or education. Similarly, further investigation of other groups could be beneficial, for example to test the effects of having tested positive on their opinions or behaviours. There was a slightly higher proportion of participants who had tested positive than the national proportion (4% vs 3%), and quite a few participants reported they had been otherwise affected by the virus, and it is possible that some participants were drawn to the study for this reason. However, this group was not excluded or highlighted in this paper due to the overall low numbers of self-reported positive cases among respondents.

Finally, as with all self-report studies, in addition to the potential oversubscription of closely affected participants, there is a possibility of other reporting biases in this study, for example social desirability bias and overreporting of compliance to self-isolation advice. However as described above, a non-trivial number of participants did report not complying at all or not intending to comply, although it does seem there is a tendency to overstate intentions. It would be interesting to relate this to actual recorded behaviour with regards to self-isolation.

Conclusions

This paper adds to the existing evidence surrounding digital contact tracing by reporting an investigation of acceptance of a live app, which had been available to download for almost 3 months at the time of the study. Based on the Technology Acceptance Model with the added factor of trust, an online survey was carried out looking at use of and attitudes towards the UK's test and trace app, NHS Covid-19, among a representative sample of participants, including subgroup analysis of the over 65 year-olds and members of the (BAME) community, as potentially vulnerable users. Results indicate that uptake was limited to around one in two persons. Stated reasons for adoption predominantly surrounded a desire to help the NHS, friends and family, and society, especially among older adults, although BAME respondents agreed significantly less that their reason was to help the NHS. However, of those with the app, only a fifth understood that the decision to send self-isolation notifications are made by the app without human involvement, and there were a range of significantly more negative views among BAME participants. Respondents without the app reported significantly lower trust and more negative views towards the app. In cohort with other studies, the evidence

shows that there are considerable barriers to the uptake of digital contact tracing apps, and these differ across different populations. It is important to consider especially potentially vulnerable groups to ensure that interventions such as these are effective. Potential users must be engaged in design to enhance uptake and acceptance of test and trace apps, focusing particularly on groups that might be hard to reach or may have different attitudes towards acceptance.

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Conflicts of Interest

None declared

Abbreviations

BAME: Black, Asian, and Minority Ethnic
NS: Non-significant

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Supplementary Files

Figures

Technology Acceptance Model (TAM2) and its relation to the current questionnaire study. Text in bold in white boxes are existing factors in TAM2 [8], followed by in bullet points examples from the questionnaire. Trust is added as an additional factor (peach box) affecting intention to use, also including examples from the questionnaire.

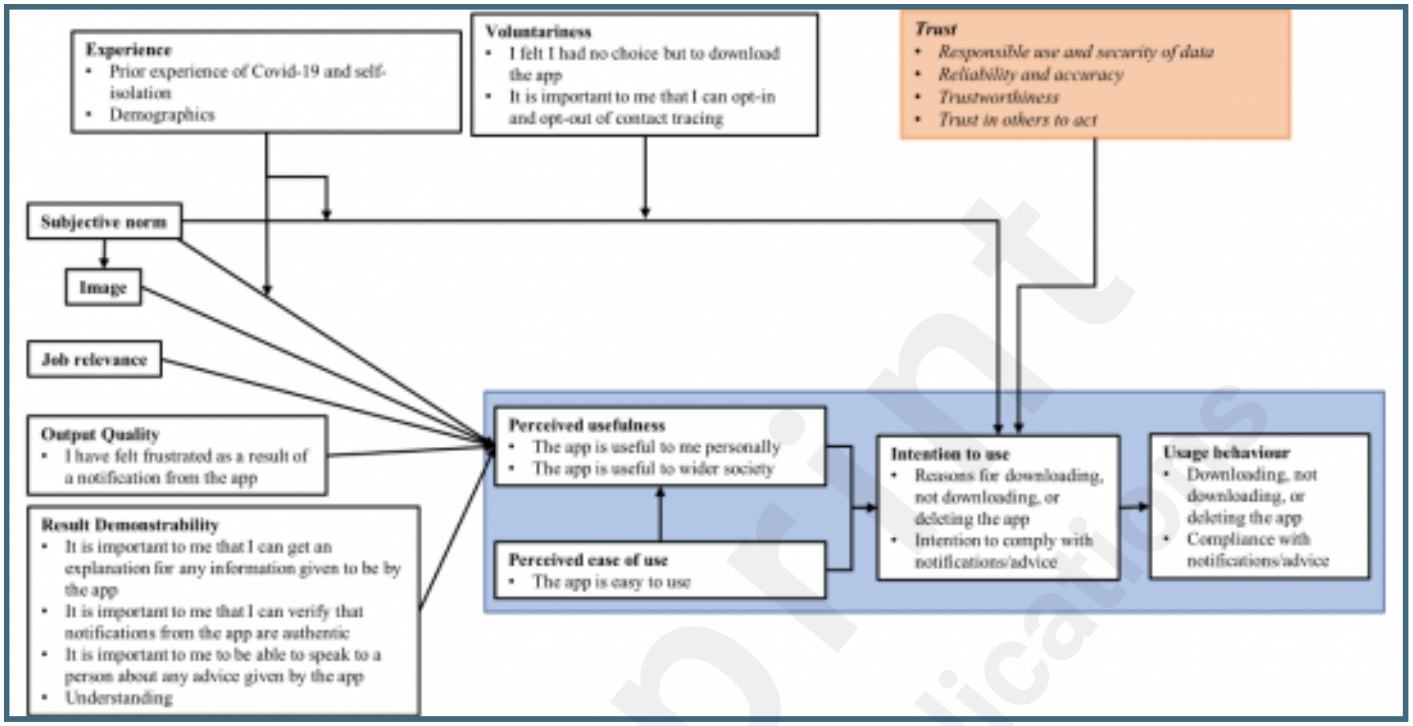
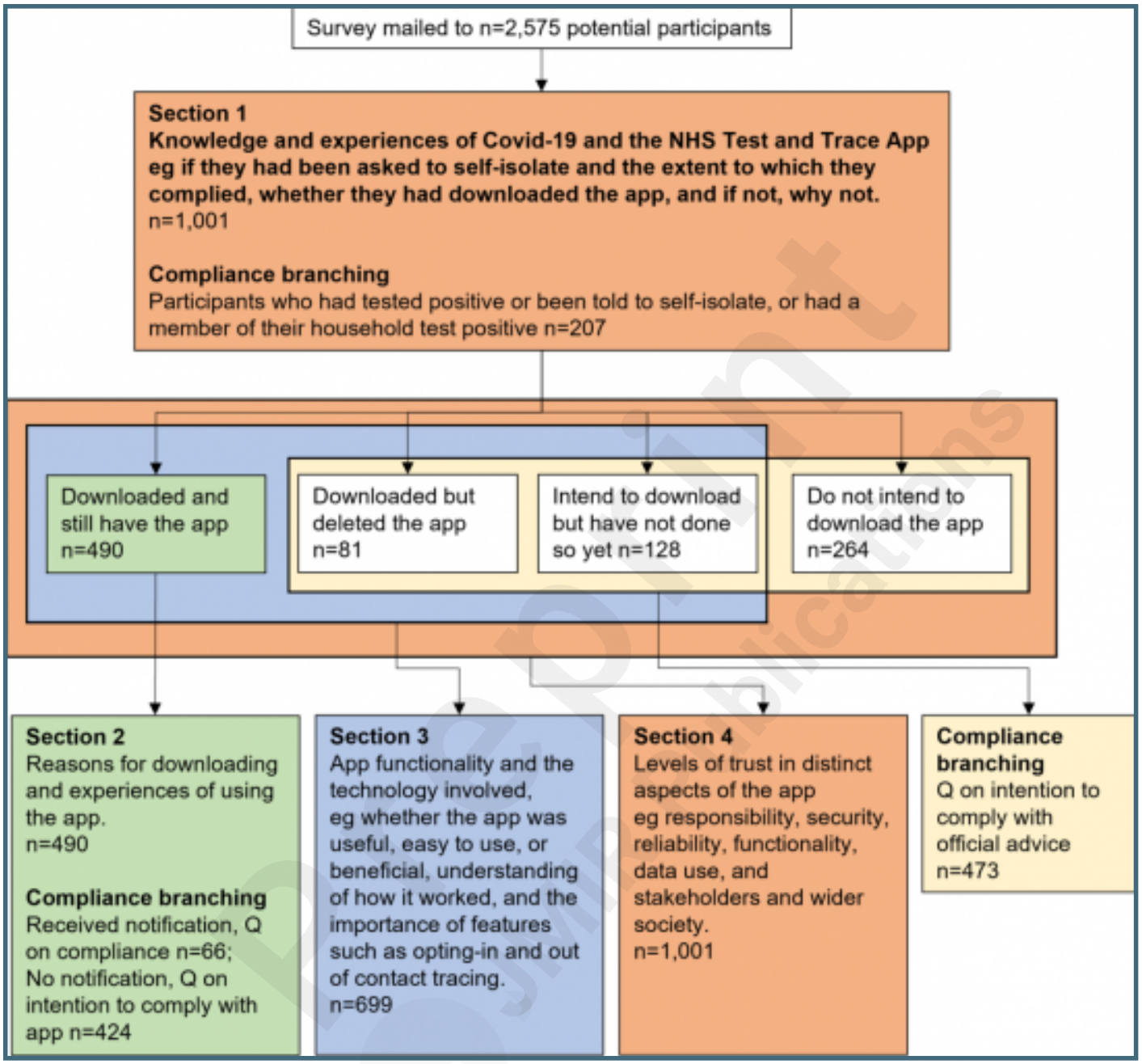
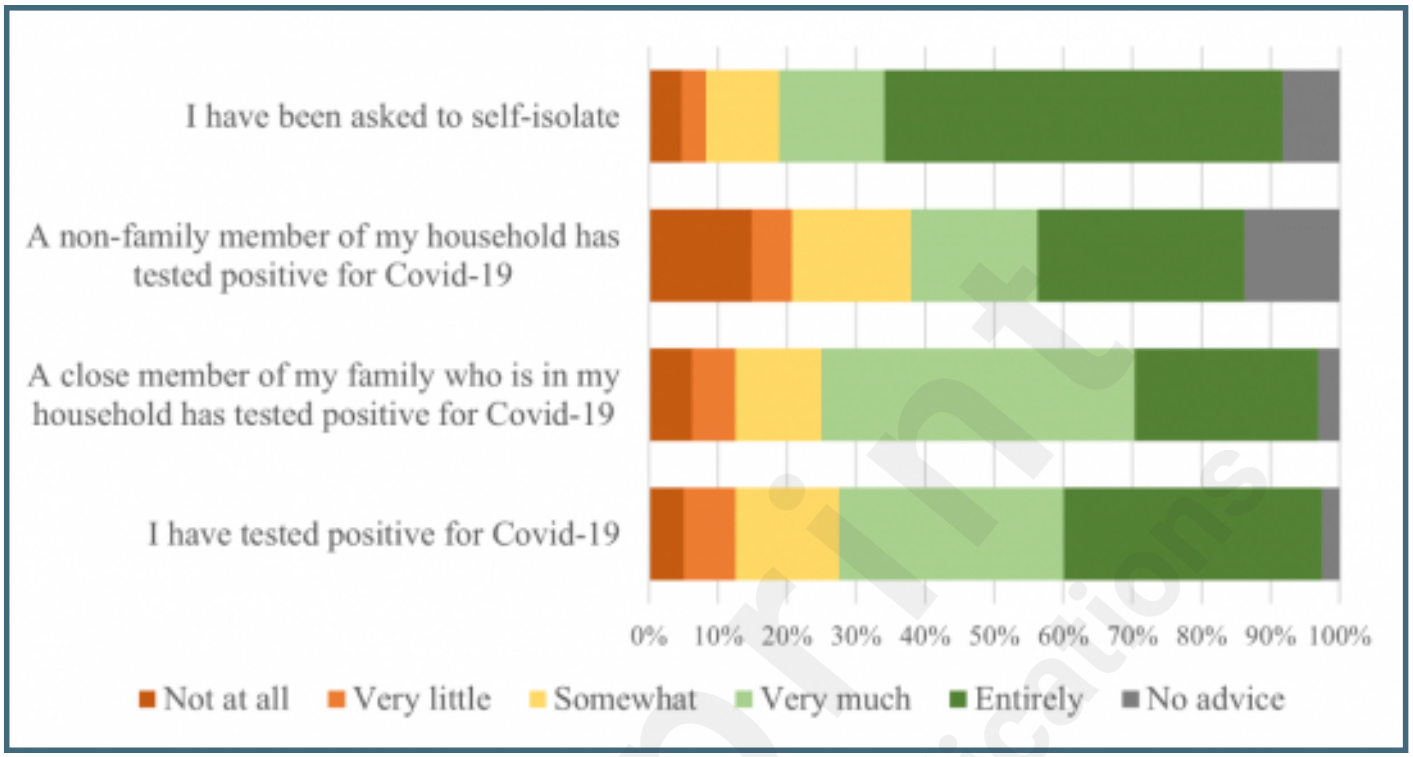


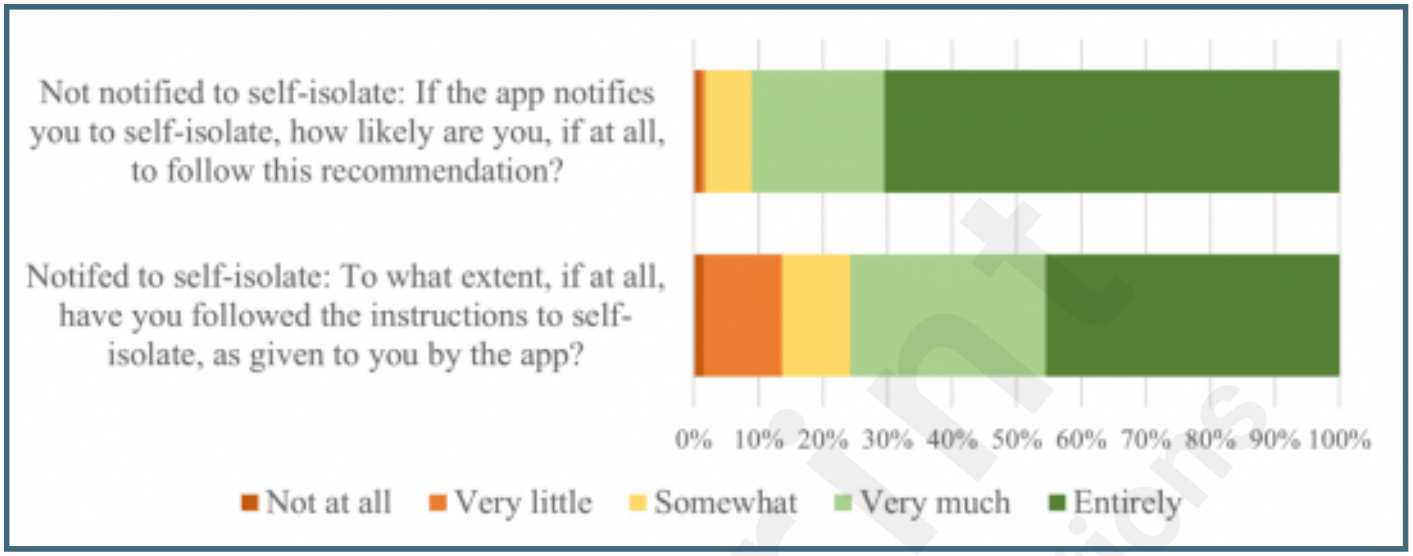
Illustration of major sections of the survey and subgroups identified for branching.



Compliance with official advice, dependent on the circumstances. Participants were asked ‘To what extent, if at all, did you follow any advice given to you?’.



Compliance and intention to comply with app notifications to self-isolate. An independent-Samples Mann Whitney U test comparing those who had received advice to self-isolate (n=66) from the app to those who had not (n=418) shows that reported intention to comply with advice is significantly stronger than reported actual compliance (mean intention=4.59, mean actual=4.06, U=17673.0, p=0.000).



Multimedia Appendixes

Demographics and additional statistics from the study.
URL: http://asset.jmir.pub/assets/e6ee86cf6540b11a7a1ed1b2b2ca138a.docx