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Behavioural pre-testing of COVID Tracker, Ireland's contact-tracing app

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Abstract: Contact-tracing mobile phone apps have the potential to play a role in controlling the spread of COVID-19, but their success hinges on widespread uptake by the public. We report a study that behaviourally pre-tested COVID Tracker, Ireland's contact-tracing app, prior to its launch with a large sample of smartphone users. The study was funded by the Department of Health and run in co-operation with the app's developers, NearForm. Participants were randomised to receive different versions of a trial app. They responded to an online survey while downloading and using the app on their phones in real time. The experimental manipulations focused on three broad areas: (i) the level of privacy assurance provided in the app, (ii) the goal-framing of the purpose of the app and (iii) the structuring of the exposure notification received by users if they are recorded as a close contact. Almost one in five participants mentioned privacy concerns in relation to their likelihood of downloading the app. Including additional assurances regarding the privacy of users' data in the app successfully lowered participants' privacy concerns and boosted engagement. This finding fed into the final version of the app released in July 2020. We also found minor beneficial effects of restructuring the exposure notification, but did not find any significant differences between two different types of goal-framing, other than a subtle effect on how the exposure notification is interpreted. Overall, our results demonstrate the value of pre-testing contact-tracing apps from a behavioural perspective to boost uptake, trust and participation.

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1. Introduction

Contact-tracing mobile phone apps have been heralded as a potentially useful tool for controlling the spread of COVID-19, but their success hinges on widespread uptake and use [1, 2, 3]. Thus, an effective design process for an app of this type must consider not only its technological functionality but also how it is perceived by the public, and how individuals interact with the app on a behavioural level [4].

A number of studies have addressed people's hypothetical likelihood of downloading a contact-tracing app, and the factors determining this [5, 6, 7, 8, 9]. We go beyond this and describe a pre-registered behavioural experiment that pre-tested different versions of an actual government-backed app - "COVID Tracker", Ireland's contact-tracing app.[1] The study was funded by the Department of Health and run in co-operation with the app developers, NearForm. Participants responded to an online questionnaire while going through the process of actually downloading the app to their phone and using it in real time. The study focused on three broad areas: the level of privacy assurance provided in the app, the goal-framing of the purpose of the app, and the structuring of the exposure notification received by users in the event that they are recorded as a close contact.[2]

The trial took place in early June 2020, at a time when cases of COVID-19 in Ireland had declined significantly and restrictions were gradually being lifted. The government had announced the development of a contact-tracing app as early as March 2020, which received coverage in the national media [10]. The COVID Tracker app's primary aim is to facilitate contact tracing, using the technology developed by Apple and Google [11]. It also contains an "Updates" tab with up-to-date information about the spread of the virus, and a "Check-In" feature, whereby users can anonymously record their symptoms (or lack thereof) on a daily basis. The app's subsequent launch in July 2020 was largely viewed as successful by international standards, with over 1 million people (of a total population of 4.9 million) downloading the app in the first 48 hours [12, 13].

Our hypotheses and the reasoning behind them are outlined below.

Privacy assurances

The international conversation surrounding contact-tracing apps has centred on privacy and concerns about the potential "tracking" of citizens [14, 15, 16, 17, 18]. This has prompted the development of privacy-preserving solutions, such as the Bluetooth-based technology used by COVID Tracker [11]. However, protecting privacy is just one task; reassuring the public that their privacy is adequately protected is another. Results from an earlier small-scale qualitative study regarding the COVID Tracker app suggested that some users would like further information about what data is processed by the app

[1] https://covidtracker.gov.ie/

[2] The full pre-registered design can be found at https://osf.io/3nd7v. An additional area of focus was to be the "Updates" tab of the app, which contains the latest information about the spread of the virus. Unforeseen limitations on the availability of statistics that were to be displayed in an alternative version of this tab meant that this intervention could not be run as intended. The results from this intervention are therefore not presented here as no robust conclusions can be drawn from them. Participants' responses to open text answers revealed a preference for receiving more localised information about the spread of the virus, as well as statistics on recoveries, and a reminder of current restrictions. These findings were provided to the Department of Health.

[19]. Successfully allaying any fears concerning privacy can only be beneficial, provided it is done in an honest and transparent way.

Multiple surveys have found that people's reported likelihood of downloading a contact-tracing app is influenced by how well their privacy would be protected [7, 6, 5, 9]. However, it cannot be assumed that hypothetical responses translate to real-world behaviour. Individuals' privacy concerns are, in fact, generally unmatched by their actual privacy-preserving behaviour – a phenomenon known as the "privacy paradox" [20]. There is also evidence that privacy concerns are lower where there is a perceived global benefit to the public at large [21]. While this suggests that public concerns about privacy may not be as large a barrier to app uptake as feared, the matter warrants further investigation in a less hypothetical situation.

Individuals tend to have fewer privacy concerns and be more willing to share their data if they are assured that their data will not be shared with third parties, if they have a greater perception of control over their data, or if they are given a justification for the collection of data [22, 23, 24]. However, interventions that increase the salience of privacy issues have sometimes made people less inclined to share data [25, 26]. Thus, we reasoned it would be useful to test whether providing additional assurances regarding privacy within the app might lessen users' concerns. Nonetheless, we acknowledged that assurances could backfire should they confer excessive salience to privacy issues.

Our hypothesis regarding privacy assurances was as follows:

- H1. Providing additional assurances about privacy issues should increase understanding of these issues, reduce concern, promote trust, and increase people's willingness to give consent and engage with the app.

Goal-framing

Presenting one good reason in favour of a particular choice can sometimes be more effective than listing all reasons available [27]. Thus, we reasoned it could be beneficial to frame the use of the COVID Tracker app (and the appropriate action to take in the case of being detected as a close contact) in terms of a single primary goal, and sought to test two candidates for this.

We previously identified the trade-off between making progress in lifting restrictions on social and economic activity and staying safe as a key driver of perceptions and judgements of Ireland's COVID-19 exit strategy [28]. This trade-off was also evident in communications from the National Public Health Emergency Team at a time when restrictions were being lifted, which recognised the need to reopen society to make people's lives easier, but emphasised the need to maintain safety.[3] Further, a willingness to protect family and friends has been identified as one of the main reasons people might be in favour of a contact-tracing app [6, 8]. Thus, in one condition we framed the app as a crucial component in the process of lifting restrictions, which reduces the chance users will spread the virus to someone vulnerable.

[3] See for example https://www.gov.ie/en/press-release/13375-statement-from-the-national-public-health-emergency-team-friday-5-june/

The coordinated effort against COVID-19 involves individuals deciding whether to make small sacrifices for the benefit of the larger group [29]. Adoption of a contact-tracing app is another part of this picture, as its use does not necessarily confer protection to the individual concerned but rather empowers them to protect those around them. Indeed, a sense of responsibility to the community was another primary reason people gave in favour of a contact-tracing app [6, 8]. Our second condition framed the app using techniques that have been shown to enhance co-operation in such "collective action problems" – using clear statements that foster a strong group identity, with articulation of how downloading the app is "best for all" [30, 31, 32].

Our hypotheses regarding the goal-framing manipulation were as follows:

- H2. How the purpose of the app is framed will affect how likely people are to download, share and use the app.
- H3. The reason given for the need to restrict movements after receiving a close contact exposure notification will affect how people react to this notification.

Structure of the exposure notification

Simple modifications to the way information is presented can have significant impacts on how well that information is processed. Using bullet points instead of paragraph text, separating information into clear categories or themes, reducing text and using headings can all increase the speed at which information is absorbed and improve recall [33, 34, 35, 36, 37, 38, 39, 40]. We previously showed that employing these techniques can improve recall of instructions regarding self-isolation in the context of COVID-19 [41]. We therefore set out to do something similar with the instructions regarding restricting movements contained in the exposure notification that app users receive if they are recorded as a close contact.

Our hypothesis with regards to this manipulation was as follows:

- H4. Structuring the exposure notification using simplified bullet points under themed headings will improve comprehension of the instructions contained within it.

2. Method

Participants recorded responses in real time on their computer/tablet as they downloaded and used the COVID Tracker app on their phones. The study was run online, and consisted of two surveys, programmed using Gorilla Experiment Builder [42]. During the first survey, participants were given instructions on how to download a trial version of the app to their phone, and were prompted to focus on different aspects of the app while responding to the questionnaire. They received different versions of the app depending on which experimental conditions they were randomly assigned to. They were then invited to use the app as much or as little as they liked before responding to the follow-up survey 3-4 days later.[4]

Participants

Participants were recruited from a large online panel held by a leading market research and polling company. Respondents were issued with an email invite to take part based on a sociodemographic quota. They were informed beforehand that the study concerned the COVID Tracker app, and that they would be required to download a trial version of the app to their smartphone. The invite link allowed only one response per person.[5] The sample was selected to be nationally representative by broad sociodemographic category, with a modest under-representation of older age groups to reflect age differences in smartphone ownership [43]. Sociodemographic characteristics of the sample are summarised in Appendix A.

Although there can be issues with selection biases in online panels [44, 45], these are less of a concern here since the target sample are already smartphone users (and therefore most likely internet users). Given the need to generate results rapidly, and the advantage of online panels in relation to minimising social desirability bias [46, 47], we judge our approach to be justified in the current context.

A sample of 1,000 participants was originally planned, based on the recruiter's prediction that 80% of participants would successfully download the app and complete the study. As recruitment progressed, it became apparent that this figure was an overestimation, with approximately one-third of participants failing to download the app. Therefore, recruitment was extended to a final sample of 1,236 to ensure that a sufficient number of participants downloaded and used the app, thereby preserving statistical power.

Participants received a payment of between €5 and €12 for their time, depending on whether they completed both surveys or the first survey only.

[4] We had originally planned to use aggregate data collected within the app itself as part of our study. However, due to anomalies within this dataset we judged it to be unsuitable for analysis.

[5] For further details on quality control of the online panel we used, see https://redcresearch.ie/techniques/online-research/

Materials and Design

Experimental manipulations

Before describing the study in detail, we first outline the three main experimental manipulations that were applied to materials within both the survey interface and the app itself in order to investigate our primary hypotheses. The baseline content of the app had previously been reviewed by members of the National Public Health Emergency Team Behavioural Change Subgroup, and additional suggested refinements were provided by a behavioural economist in the Department of Health.

The experimental manipulations were run orthogonally, resulting in a 2 x 2 x 2 design. Further detail regarding the appearance and wording of manipulations can be found in Appendix B.

Privacy assurances

This manipulation was applied within the app itself wherever there was information about data or privacy: at several points during the on-boarding process of the app, and in the "Check-In" tab.

Participants were randomly allocated to one of two conditions:

- "Baseline": This was the baseline wording provided by app developers, which contained the minimum required information about data processed by the app.
- "Baseline + Privacy Assurance": This contained exactly the same information as the baseline condition, but with additional assurances about the privacy of users' data, written in bold font.

Goal-framing of the app

This manipulation was applied at three points:

1) In the text of a "call-to-action" that participants saw within the survey interface prior to downloading the app.
2) Within the app itself, in the text and images used in the introductory screen and when users are asked to enable the contact-tracing technology on their phone.
3) In the text of a sample exposure notification that participants were shown in Survey 2.

Participants were randomly allocated to one of two conditions:

- "Safe Progress" frame: The app was presented as a technological solution to allow life to return to normal while keeping everyone safe. In the sample exposure notification, participants were told to restrict their movements to "avoid infecting someone vulnerable".
- "Collective Action" frame: The app was presented as a collective solution to allow everyone to play their part in the fight against COVID-19. In the sample exposure notification, participants were told to restrict their movements to "play your part to stop the spread".

Structure of the exposure notification

The sample exposure notification was shown to participants within the survey interface in Survey 2.

Participants were randomly allocated to one of two conditions:

- "Control": This was the baseline version provided by app developers, with some minor changes such as the addition of a rationale for restricting movements, as mentioned above.
- "Intervention": This contained the same information as the control condition, but simplified and rearranged as bullet points under themed headings.

Survey 1

Call-to-action

Prior to downloading the app, participants were asked to read a "call-to-action", which introduced the purpose of the app and its three main functions (contact tracing, symptom check-in and information updates) over two screens (see Appendix B). Following this, participants were asked questions about:

- How likely they would be to download the real app and why.
- How useful they would find the app, and how helpful it would be for tackling the pandemic.
- How important it is that everyone downloads the app, how likely they would be to recommend others to do so, and how fair it is to ask everyone to do so.
- Their overall impression of the app.

Responses were recorded on 7-point scales, plus one open text answer for outlining the reasons for their stated likelihood of downloading the app. Participants were also asked to estimate what percentage of smartphone owners they thought would download the app, by clicking on a scale.

Download instructions

Participants were then given detailed instructions on how to download the trial COVID Tracker app.[6] They were given a code to enter on first opening the app. This determined which version of the app they received, depending on which experimental conditions they had been randomly assigned to. Participants were made aware that the app was only a trial version and that contact tracing would not actually be active.

Participants were given multiple opportunities to flag if they were unable or unwilling to download the app. Participants who did so were then asked the reason for this, before proceeding to the final section of the survey (explanatory and sociodemographic variables).

Participants who successfully downloaded the app were instructed to complete the "on-boarding" process of the app on their phones before returning to the survey. This involved receiving information about data privacy within the app, giving consent for the collection of anonymous data about their app usage (optional), enabling the contact-tracing technology on their phone (optional), and providing a phone number to receive a call back if an exposure notification is received (optional and only asked if contact tracing was enabled). A "holding page" was inserted into the app to instruct participants to return

[6] This was a two-step process: iOS users needed to first download an app called TestFlight, while Android users had to first join a Google group in order to then download the trial app.

to the survey at the end of the on-boarding process, ensuring that participants completed the relevant part of the questionnaire immediately afterwards.

Consent

After completing the on-boarding process, participants were asked if they had consented to the following:

- Sharing anonymous data about their app usage.
- Enabling the exposure notification service on their phone to facilitate contact tracing.
- Sharing their phone number; thereby opting in to receive a call back if they were to receive an exposure notification (only asked if they had enabled contact tracing).

Participants were also asked if they would make the same decisions about sharing their data if using the real app.

Participants were then asked to turn their attention to the "Updates" tab of the app, followed by the "Check-in" tab, where it is possible to share daily information about symptoms, with the option of sharing additional anonymous information (age, sex, locality) to make the data more useful. Participants were asked:

- If they checked in their symptoms, or lack thereof.
- If they shared any additional optional information (only participants who checked in).

General impressions

Participants were given the option to spend more time looking at the app before responding on 7-point scales to general questions about:

- How useful the different features of the app (contact tracing, daily check-in, updates tab) would be for them.
- How effective they thought the app would be, and how much of a difference they felt they could make by using the app.
- How worried they had been feeling about the lifting of social distancing restrictions, and how much more or less worried they would be about this if the app were launched.

This was followed by a multiple-choice question (MCQ) asking how often they thought they would use the app.

Privacy concerns

Next, participants were asked a series of questions relating to privacy. They were asked if they had clicked on a link to the Data Protection Information notice at any point. They then responded to a series of 7-point Likert items relating to:

- Their trust that their data would be used appropriately, that no information would be accessed other than that which they consented to, and that they can update their preferences whenever they wish.

- Their self-reported privacy concerns at different points (when asked to share app usage data, when asked to enable the exposure notification service, when asked to share a phone number, when asked to share information for the daily check-in).
- Their self-reported understanding of the data processed by the app and the phone features they need to enable.

This was followed by four comprehension questions. Participants were asked to identify from a list (selecting all correct answers) what (a) personal, and (b) anonymous data is processed by the app. They were also asked what steps they needed to take to (a) receive exposure notifications, and (b) keep a record of their symptoms and receive advice on these.

Explanatory and sociodemographic variables

Participants were asked questions about broader opinions and attitudes that we anticipated may be related to their attitude to a government-run contact-tracing app. Participants responded to 7-point Likert items concerning:

- Their privacy concerns when using the internet and mobile phone apps.
- Their awareness of media coverage (positive or negative) concerning COVID Tracker.
- Their anxiety surrounding COVID-19 and its potential effect on them personally.
- Their trust of the government, in relation to their handling of the pandemic and more generally.

Following this, participants responded to standard sociodemographic questions.

Survey 2

Follow-up questionnaire

Participants were first asked how often they used the app, for how long (in minutes), and for what purpose. They were also asked if they tried to share the app. They then responded to some questions repeated from the first survey about:

- How likely they would be to download the real app.
- How useful the different features of the app would be for them.
- How effective the app would be and how much of an impact it would have.
- How much more or less worried they would be about the lifting of restrictions if the app were launched.
- How important it is that the app is widely used and what percentage of smartphone owners they thought would download it.
- How easy they found the app to use and their overall impression of it.

They were also asked to imagine they have tested positive for COVID-19 and to rate their likelihood of allowing the app to notify other users they have been in contact with on a 7-point scale.

Exposure notification

Next, participants were shown (within the online survey interface) the exposure notification screen that users receive if they are recorded as a close contact, with advice of what to do and not do.[7] The content of this notification was subject to a 2 x 2 manipulation of both the goal-framing of the advice to restrict movements, and the structuring of the information on how to do so.

Participants were asked to indicate on 7-point scales how worried receiving this notification would make them feel, how confident they would be about knowing what to do or not do, and how likely they think it would be that they have COVID-19 if they received a notification. They were also asked what the *first* thing is they would do if they received this notification.

Following this, participants were asked three MCQs to gauge how well they understood the advice in the notification. They were asked about the best way to arrange a test, how to behave if they received the notification but weren't experiencing symptoms, and how to behave if they received it and started experiencing symptoms.

Finally, participants were asked to respond to a series of four short vignettes, each describing a scenario in which an individual has received a close contact notification but decides to ignore some of the advice on restricting movements. Participants were asked to judge the acceptability of these decisions on a 7-point scale.

[7] For ethical reasons these notifications were not sent through to the app on their phone, in case they were mistaken for a real notification.

3. Results

The first survey was completed by 1,236 participants, while an additional 341 commenced but did not complete it, meaning their data was not recorded. Of the participants who completed Survey 1, 27 were excluded from analysis as they stated that they did not have a smartphone, despite having been told this was a requirement to take part. This resulted in a final sample of 1,209 participants. Of these, 372 did not download the app, completing only the shorter version of Survey 1. For the vast majority this was due to issues with downloading and installing the trial app.[8] Just 3% of participants who did not download the app said it was because they did not feel comfortable doing so. A further 16 participants did not report issues with downloading the app when initially asked, but later revealed through open text responses that they had failed to download it or encountered technical difficulties. Data from these participants in relation to their experience with the app were therefore excluded. A final total of 821 participants successfully downloaded and used the app. Of these, 799 completed the follow-up survey.

Determinants of likelihood to download

We first present pooled results from all participants in relation to their stated likelihood of downloading the real COVID Tracker app. We do this to situate our results in relation to other surveys that have been conducted in Ireland and elsewhere, as well as to measure the prevalence of privacy concerns among participants that have not yet been explicitly prompted to think about privacy issues.

The majority of participants indicated that they would be highly likely to download the app, with 78% giving a score above the midpoint of the 7-point scale, and 62% of participants giving a score of 6 or higher (Figure 1 (a)). Participants over 60 were more likely to give a score of 6 or above (Logistic Regression, $p=0.001$, Table 1 Model 1), while men, and participants from lower social grades were less likely to do so ($p=0.001$ and $p=0.003$, respectively).[9]

These effects appear to be at least partly explained by participants' concerns about potential misuse of their personal data, anxiety about the pandemic and trust in the government. Participants who reported higher concern (above the midpoint of the scale) about the misuse of their personal data while using mobile phone apps in general said they would be less likely to download the app ($p=0.034$, Table 1 Model 2), while those who were more anxious about the pandemic said they would be more likely to ($p=0.019$). Participants who trusted the government more, both in terms of their competence in handling the pandemic and more generally, said they would be more likely to download the app ($p<0.001$ in both cases). Having read or viewed coverage about the app in the media was also associated with a higher likelihood of downloading the app, on average ($p=0.004$).

[8] It should be noted that, being a two-stage process, this was a more complicated task than simply downloading a standard app. Furthermore, the app would not have been compatible with some older phones.

[9] We chose this cut-off of 1-5 vs. 6-7 as we judged it most appropriate for capturing the difference between participants who would most likely download the app from those who remain undecided, allowing the best comparison with other surveys. Taking a lower cut-off of 1-4 vs. 5-7 results in a weakening of the gender and age effects, but a strengthening of the social grade effect. Taking a higher cut-off of 1-6 vs. 7 weakens the gender effect but the age and social grade effect remain relatively unchanged.

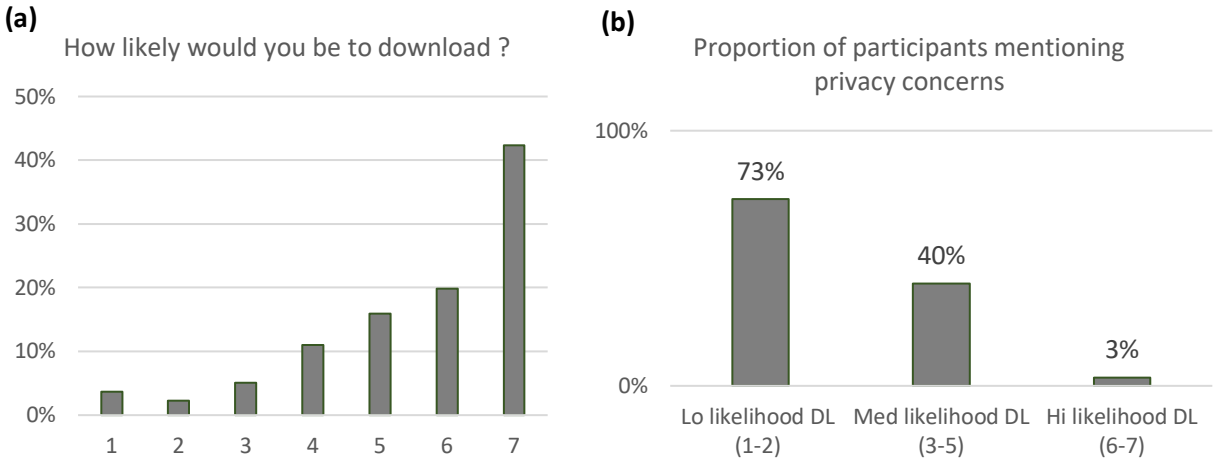

Figure 1. Pooled results showing (a) participants' stated likelihood of downloading COVID Tracker in real life, on a scale from 1 (Definitely would not download) to 7 (Definitely would download) (n=1,209) and (b) the proportion of participants mentioning privacy concerns when asked for the reason for their rating, split by whether they stated a low, medium, or high likelihood of downloading the app (n=71, n=386, n=752, respectively).

When asked to give a reason for their rating in an open text answer, 19% of participants mentioned privacy concerns of some kind. Mentions of privacy concerns were especially common among those participants who said they would be very unlikely to download the app (rating 1 or 2 out of 7), but were still prominent amongst those who gave intermediary scores (3 to 5) (Figure 1 (b)).

Participants with a degree were more likely to mention privacy concerns than those without (Logistic Regression, p=0.003, Table 1 Model 3). Participants with higher concerns about their data when using apps in general were also more likely to mention these concerns (p=0.022, Table 1 Model 4), while participants with higher anxiety about the pandemic were less likely to (p=0.004). There was a negative association between the mention of privacy concerns and perceived competence of the government in relation to the pandemic (p=0.043), and especially trust in the government in general (p<0.001). Having seen coverage about COVID Tracker in the media did not appear to lead to more or fewer privacy concerns regarding the app.

Table 1. Logistic regression on whether a participant stated a high likelihood (6 or 7) of downloading COVID Tracker (Models 1 &2), and whether they mentioned privacy concerns as a reason for their rating (Models 3 & 4) (n=1,209).

	hi likelihood DL		privacy concerns	
	(1)	(2)	(3)	(4)
Gender: Male	-0.40**	-0.32*	0.19	0.08
	(0.12)	(0.13)	(0.15)	(0.16)
40-60 years (*default: under 40)*	0.05	-0.02	0.25	0.34+
	(0.14)	(0.15)	(0.17)	(0.18)
60+ years (*default: under 40)*	0.58**	0.37*	-0.33	-0.10
	(0.18)	(0.19)	(0.23)	(0.24)
Urban	0.10	0.13	-0.16	-0.19
	(0.13)	(0.13)	(0.15)	(0.16)
Degree	-0.08	-0.09	0.50**	0.55**
	(0.14)	(0.14)	(0.17)	(0.18)
Employed	0.07	0.03	-0.05	-0.03
	(0.14)	(0.15)	(0.17)	(0.18)
C1C2 social grade (*default: AB)*[10]	-0.13	-0.06	-0.11	-0.21
	(0.15)	(0.15)	(0.17)	(0.19)
Other social grade (*default: AB)*	-0.58**	-0.42*	0.03	-0.15
	(0.20)	(0.21)	(0.24)	(0.26)
Hi privacy concern internet		-0.17		0.28
		(0.22)		(0.27)
Hi privacy concern apps		-0.47*		0.64*
		(0.22)		(0.28)
Read or viewed coverage in media		0.38**		-0.17
		(0.13)		(0.16)
Hi anxiety about pandemic		0.31*		-0.46**
		(0.13)		(0.16)
Hi score gov competence pandemic		0.60***		-0.39*
		(0.17)		(0.19)
Hi trust gov general		0.75***		-1.06***
		(0.14)		(0.17)
Note:	+: p<0.1; *: p<0.05, **: p<0.01, ***: p<0.001			

[10] Social grade (A, B, C1, C2, D or E) is based on the occupation of the chief income earner in a participant's household, where A responds to the highest grade (upper middle class).

Privacy assurance manipulation (hypothesis H1)

Trust and privacy concerns

Responses to questions about trust in relation to data, and about participants' level of concern about the privacy of their data are shown in Figure 2. As there was a high level of consistency between Likert items, ratings were combined to create one score for trust and one for privacy concerns. Trust was relatively high overall, but was significantly higher among participants in the Privacy Assurance condition (Wilcoxon, Z=1.99, p=0.047), while privacy concerns were lower (Z=-2.18, p=0.029). Crucially, differences were also seen when focusing only on those participants who raised privacy concerns unprompted in the first section of the survey (Z=2.19, p=0.029 for trust, Z=-1.93, p=0.054 for privacy concerns). This was also the case if focusing only on those participants that said they would be less likely (rating of 5 or lower) to download the real app (Z=1.97, p=0.049 for trust, Z=-2.04, p=0.041 for privacy concerns).

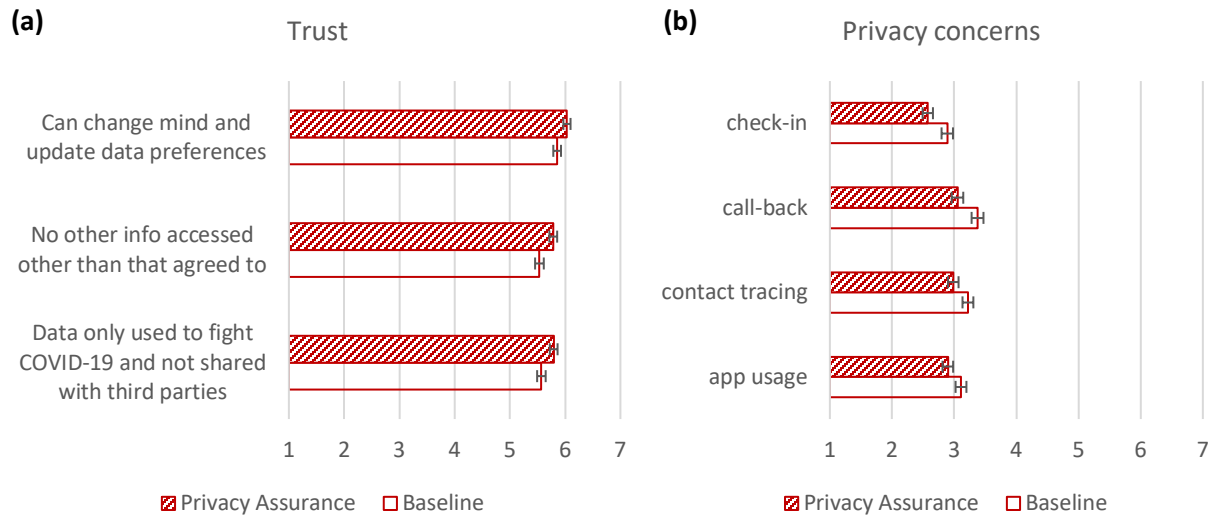

Figure 2. Responses to Likert items regarding (a) participants' level of agreement with statements about trust regarding the data they were asked to share, on a scale from 1 (Strongly disagree) to 7 (Strongly agree), and (b) participants' stated level of concern at different points when using the app, on a scale from 1 (Privacy concerns didn't cross my mind) to 7 (I was very concerned about my privacy).

Consent

Stated levels of consent to the collection of data about app usage, to participation in contact tracing (and if so, sharing a phone number to receive a call back), and reported use of the check-in feature (and if so, sharing of additional sociodemographic information) are shown in Figure 3. Consent was high overall, with the majority of participants (61%) agreeing to share all information. Consent was slightly higher among those participants in the Privacy Assurance condition, with a significant difference seen in the number of participants sharing their phone number to opt in to receive a call back in the event they were to receive an exposure notification (χ^2=4.22, p=0.04). It should be noted that only those participants who had already

consented to contact tracing were asked to provide a phone number, meaning it is possible there was a selection effect present. However, given the small difference in proportions agreeing to take part in contact tracing we judge this effect to be negligible, and in any case it should only result in a dampening of the effect seen on consent to the call back.

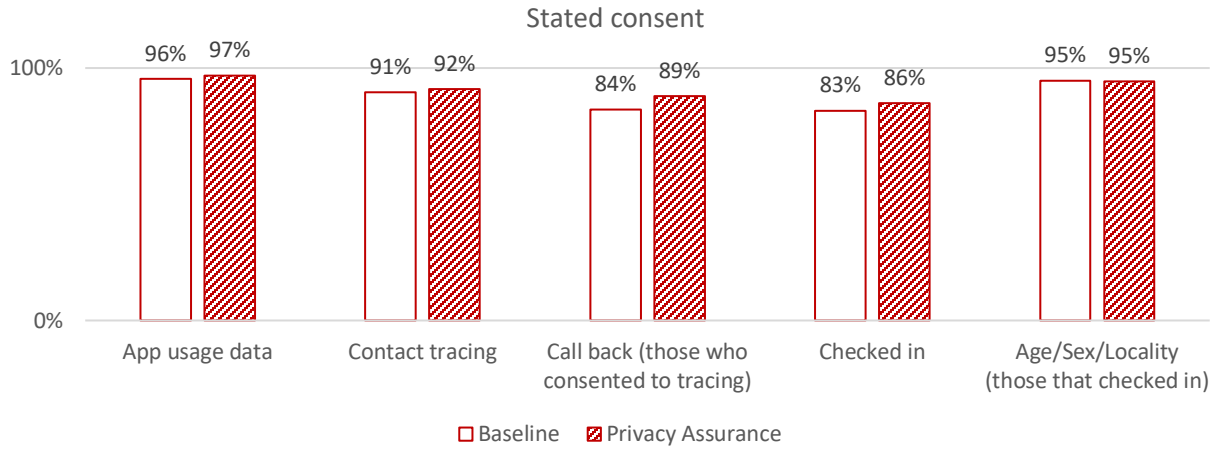

Figure 3. Stated consent at relevant points during app set-up and use. Data from participants who responded "not sure" are excluded.

A majority of participants said that they would make the same decisions in real life as they did in this study (75% for the on-boarding process, 83% for the check-in). Only a small proportion said they would be either more or less willing to share information in real life (7% vs. 8% for the on-boarding process, 4% vs. 6% for the check-in).

Comprehension

Participants' self-reported understanding of what data is processed by the app and why, and what features of their phone need to be enabled for the app to function is displayed in Figure 4 (a). Participants in the Privacy Assurance condition reported higher levels of understanding, which was statistically significant in relation to data processed by the app (Wilcoxon, Z=2.03, p=0.042), but fell just short of significance in relation to phone features employed by the app (Z=1.92, p=0.055).

However, this effect was not reflected in actual measures of comprehension. Comprehension was measured through questions about (1) personal data processed by the app, (2) anonymous data processed by the app, (3) phone features to enable to partake in contact tracing, and (4) steps to take in order to keep a daily record of symptoms. In each case, participants had to select all correct answers from a list. Very few participants selected all correct answers while not selecting any incorrect answers – only 3 participants answered all four questions correctly while 315 did not answer a single question correctly using this strict criterion. More nuanced comprehension scores were therefore created by calculating separately the percentage of correct answers chosen and the percentage of incorrect answers not chosen, and averaging these for each question, as shown in (Figure 4 (b)). Participants in the Privacy Assurance condition did not display better comprehension, and in fact performed significantly worse on the first question about personal data processed by the app, although the difference was slight (Wilcoxon, Z=-

1.96, p=0.0496). This appears to be primarily due to fewer participants in the Privacy Assurance condition selecting "IP address" as personal data processed by the app (43% vs. 52% in baseline condition).

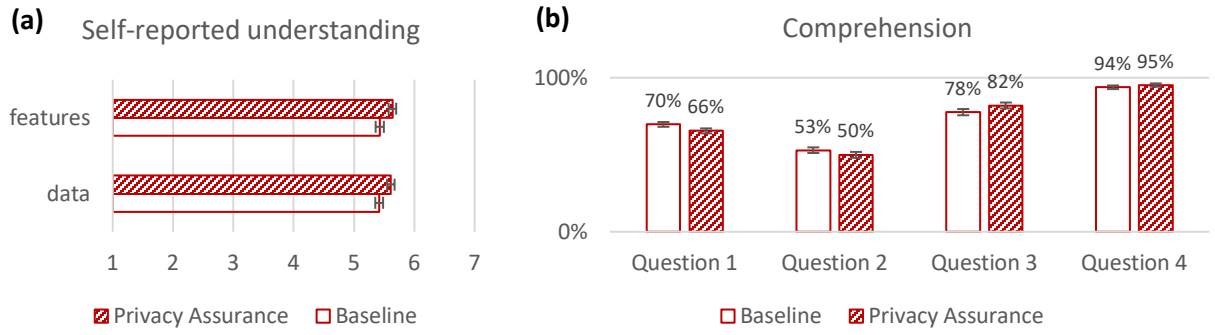

Figure 4. Participants' (a) self-reported understanding of the data processed by the app and the features of their phone utilised by the app on a scale from 1 (I didn't understand this at all) to 7 (I understood this perfectly), and (b) actual performance on comprehension questions (mean of percentage of correct options chosen and percentage of incorrect options not chosen for each question).

Other effects

Privacy assurances had unexpected effects beyond those on privacy-related outcome measures. Participants in the Privacy Assurance condition gave higher scores on questions about the overall effectiveness of the app (Wilcoxon, Z=1.97, p=0.049), and the difference they felt they could make by downloading and using it (Z=2, p=0.045) (Figure 5 (a)). There was no significant difference between the proportions of participants who mentioned privacy concerns in the first part of the survey in the baseline compared with the privacy assurance condition (χ^2=0.31, p=0.58), suggesting that these effects were due to the intervention rather than an imperfect randomisation process. These effects were still present in responses to the second survey several days later (Z=1.77, p=0.077 and Z=2.46, p=0.014, respectively) (Figure 5 (b)).

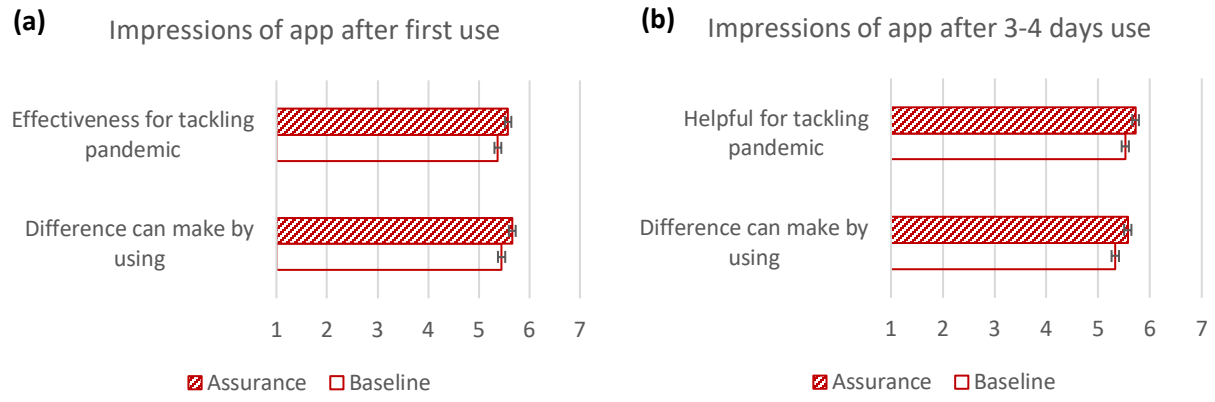

Figure 5. General impressions regarding the effectiveness of the app (a) immediately after first use (Survey 1) and (b) after 3-4 days use (Survey 2).

Goal-framing manipulations

Effects of goal-framing on app uptake and impressions (hypothesis H2)

The framing of the purpose of the app in the initial call-to-action presented to participants did not have an effect on stated likelihood of downloading the real app (Wilcoxon, Z=0.18, p=0.86). The time spent reading the two call-to-action pages was short (a median of 10 s and 18 s to read over 50 and over 160 words, respectively), so it is likely that some participants did not read these thoroughly, perhaps not realising that this was also a part of the study. However, no effects of framing were seen even when taking a median split of only those participants that spent longer on the call-to-action pages (Z=-0.24, p=0.81).

Framing did not have an effect on other indicative measures taken prior to participants downloading the app, nor did it have any effect on outcome measures subsequent to app download or in the follow-up survey. 66% of participants reported checking the app at least once a day in between the two surveys, but this proportion was unaffected by framing (χ^2=0.13, p= 0.72). Thus, no evidence was found to support hypothesis H2.

Effects of goal-framing on reaction to exposure notification (hypothesis H3)

There was no effect of goal-framing on how worried participants said they would feel, were they to receive an exposure notification (Wilcoxon, Z=-1.15, p=0.25). However, participants thought it would be more likely that they have COVID-19 were they to receive such a notification if they had been told to restrict their movements to play their part in stopping the spread of the virus, rather than to avoid spreading the virus to someone vulnerable (Z=2.16,p=0.03) (Figure 6).

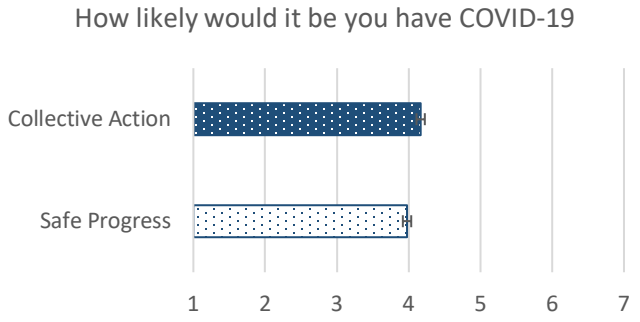

Figure 6. Stated presumed likelihood of having contracted COVID-19 if an exposure notification were received, assuming no symptoms are being experienced, on a scale from 1 (Extremely unlikely to have COVID-19) to 7 (Extremely likely to have COVID-19).

Goal-framing did not affect participants' cautiousness, as measured by a composite score of responses to four vignettes describing individuals failing to fully follow the advice in the exposure notification (Wilcoxon, Z=0.76, p=0.45). Participants were generally conservative, giving an overall median response of 2 on a scale from 1 (Completely unacceptable) to 7 (Completely acceptable) in response to these scenarios.

Structure of exposure notification intervention (hypothesis H4)

Participants who received the intervention version of the exposure notification said they would be slightly more confident in knowing what they should and should not do if they were to receive such a notification (One-tailed Wilcoxon, Z= 1.95, p=0.025) (Figure 7(a)). Any effect of the intervention on comprehension, as measured by performance on three MCQs, one about how to arrange a test, and two about how to behave after receiving the exposure notification, was marginal (One-tailed Wilcoxon, Z= 1.29, p=0.099)(Figure 7(b)).[11]

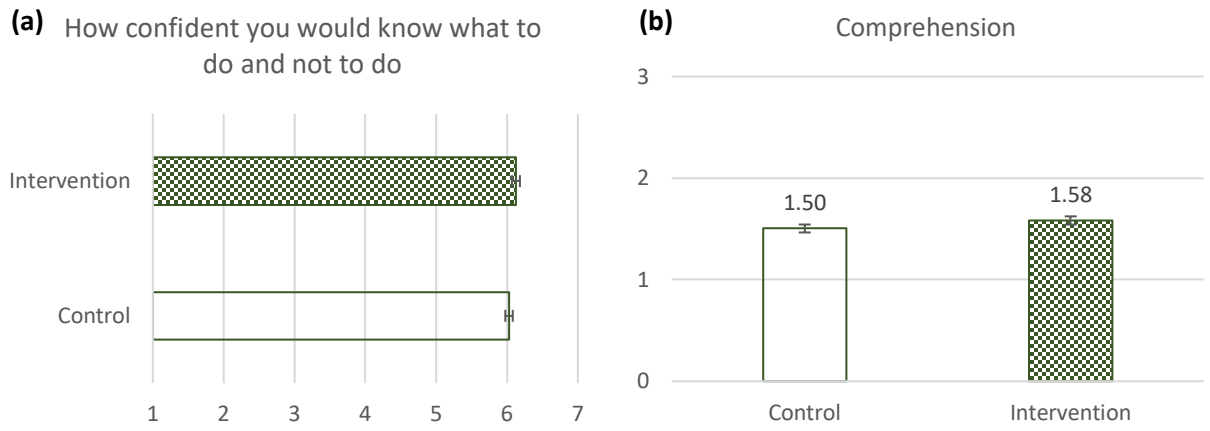

Figure 7. (a) Stated confidence in knowing what to do and not do if an exposure notification were to be received on a scale from 1 (Not at all confident) to 7 (Very confident), and (b) number of correct answers to comprehension questions regarding what to do and not do if a notification were received.

[11] Closer inspection of responses to the question "Imagine you received a close contact exposure notification, but were not experiencing any symptoms. Which of these pieces of advice most accurately matches the guidelines you saw?" revealed that as many as 46% of participants incorrectly selected "Follow general advice but monitor your symptoms" as the answer. This was intended to mean following the general advice that everyone in the country has been given, but given the large proportion selecting this option (considerably larger than the 30% that selected the correct answer), it is possible that some of these interpreted it instead as following the advice they were given in the exposure notification. If these responses are excluded, the intervention did in fact have a significant positive effect on comprehension, but no conclusions can be drawn at present.

4. Discussion

The results of this study suggest that, prior to its launch, smartphone users in Ireland held a generally favourable view of the COVID Tracker app and a majority were open to downloading it. It should be noted that participants were told in advance what the subject of the study was, which may have led to some selection bias in our sample with regards to existing attitudes towards the app. That said, our results are in line with high levels of public support recorded in other surveys, including one conducted in Ireland in May 2020 in which 83% of respondents indicated they would either "probably" or "definitely" install the app [6, 8]. We found trust in the government to be the strongest mediator of stated likelihood of downloading the app, in line with other studies [6].

Almost one in five participants mentioned privacy concerns when asked for a reason for their stated likelihood of downloading the app, and these concerns were especially common among those participants least likely to download it, in line with previous studies [7, 6, 5, 9]. Given our use of an online sample of participants, who had already consented to share their data for the study, this level of privacy concern is likely to be an underestimation of that present in the general population. Crucially, while participants in other surveys were prompted to think about privacy, either by being asked explicitly or through mentions of privacy in the description of the app they received, there was no prior mention of data privacy in our study at the point that this question was asked. This suggests that privacy in this context is a genuine issue for a substantial proportion of people in Ireland, and not just the preoccupation of a very small but vocal minority. Further support for this comes from the lack of a relationship between the mention of privacy concerns and having seen or read coverage about the app in the media.

Including additional privacy assurances within the app successfully lowered participants' privacy concerns and increased their trust. Importantly, this was also true of those participants who were more hesitant about downloading the app, or who had mentioned privacy concerns unprompted. While a difference in levels of engagement was only detected with regards to sharing a phone number, this may have been the result of a ceiling effect, as consent was generally high. Overall, our results provide evidence for most of hypothesis H1, regarding the effectiveness of privacy assurances in reducing concern, promoting trust, and increasing people's willingness to engage with the app. We also found spill over effects of the additional assurances on more general perceptions of the app, with participants receiving the assurances having a more favourable view of the effectiveness of the app.

One aspect of hypothesis H1 that was not verified, however, concerned the effect of privacy assurances on understanding of privacy issues. Although participants who saw the additional assurances self-reported better understanding of what data is processed by the app and what features of their phone it uses, this was not reflected in more objective measures of comprehension. This highlights an important point regarding the ethics of how privacy information is communicated – while simple techniques can be used to lessen app users' concerns and boost engagement, one must be careful not to employ these in a way that misleads users, even if it is unintentional. Participants' comprehension of the data used by the app remained low overall.

We found no evidence to support hypothesis H2 – there were no differences in likelihood to download, share or use the app whether it was framed as a tool that allows us to stay safe while lifting restrictions,

or as a collective solution that can help everyone play their part in tackling the virus. It is possible that participants held their own pre-existing views on the benefits of contact tracing that overrode those reasons presented through the goal-framing. It is also possible that high levels of support produced a ceiling effect, preventing more subtle differences from being detected. Of course, it remains possible that both frames were simply equally effective: in a previous study we failed to find a difference between two different messages for motivating social distancing, although both performed better than a control [48].

Our results provided minor support for hypotheses H3 and H4 regarding the sample exposure notification. Participants in the "Collective Action" condition thought it would be slightly more likely that they have COVID-19 should they receive a notification than participants in the "Safe Progress" frame. Although this was not a direct intended effect of the manipulation, it may mean participants would be more likely to act as though they have the virus and therefore be more cautious. Participants who received the intervention version of the exposure notification structure said they would be slightly more confident in knowing what they should or shouldn't do were they to receive the notification, although this did not unambiguously translate into better comprehension. Nonetheless, a simple reduction in perceived uncertainty may be beneficial for adherence to the guidelines [49]. Although the effect size of the two exposure notification manipulations was modest, they may still make a significant contribution given the size of the app's target audience and the importance of maximising engagement.

Although our study demonstrates the value of pre-testing features of a contact-tracing app, some of which were subsequently adopted for the final design of Ireland's app, caution must be exercised in extending these results to other contexts or other countries. One of the likely reasons COVID Tracker was well received is that trust in the Irish government was generally high in the earlier stages of the pandemic, and the app was branded in a way that clearly situated it within a coherent set of state communications. Trust has been shown to be a central factor in levels of privacy concern [50]. Another important factor was the timing of this study and the app's launch. We found anxiety about the pandemic to be one of the drivers of likely app uptake, in agreement with another Irish survey [8]. Anxiety may have been heightened at the time of this study due to the lifting of restrictions, and different results may have been found at a different point in the virus's trajectory.

Despite these limitations on the generalisability of precise results in this report, the study's general approach is of wider value. Although we do not advocate using our findings as a blueprint for app designs elsewhere, our study shows that behaviourally pre-testing contact-tracing apps is a feasible and worthwhile exercise, even under considerable time pressure.

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6. Appendices

Appendix A – Sociodemographic characteristics of the sample

		Participants who downloaded		All participants	
		n	**%**	***n***	**%**
Gender	**Men**	401	49	604	50
	Women	420	51	605	50
Age	**Under 40**	345	42	451	37
	40 – 59	330	40	484	40
	60 +	146	18	274	23
Education	**Degree or above**	405	49	565	47
	Below degree	416	51	644	53
Employment	**Employed**	528	64	735	61
	Not employed	293	36	474	39
Urban-Rural	**Urban**	541	66	770	64
	Rural	280	34	439	36

Appendix B – Experimental manipulations

Privacy assurance manipulations

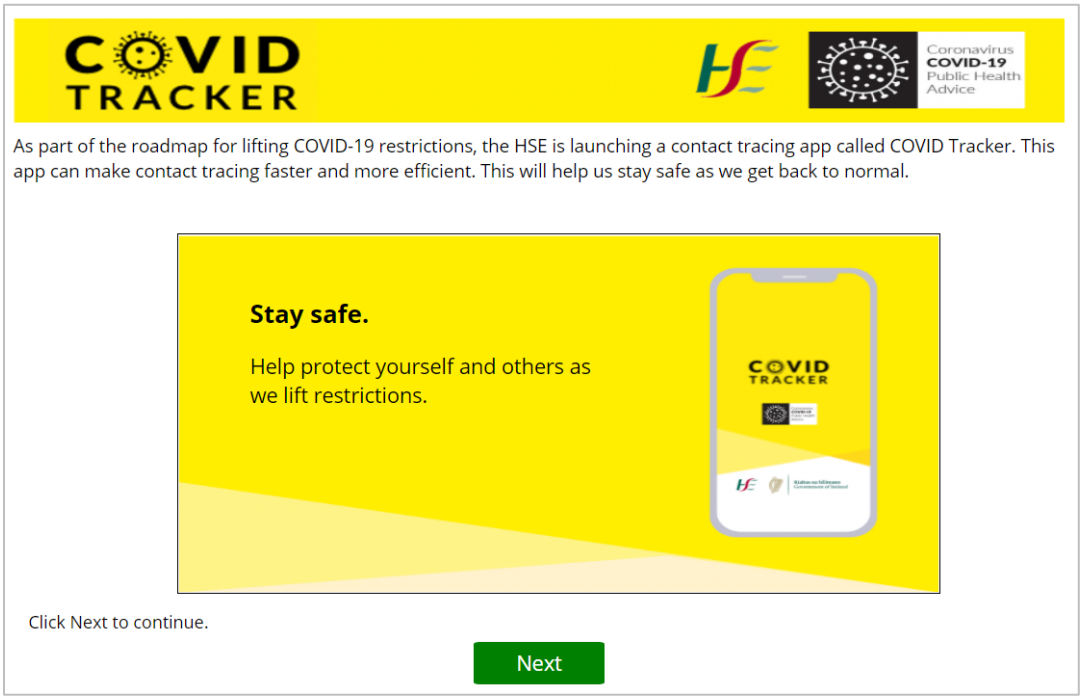
App screen	Baseline	Privacy Assurance
Your Data	This app supports contact tracing while maintaining privacy. The only personal data collected by the app is your IP address and your phone number, should you choose to share it with the HSE to receive a follow-up call for contact tracing. Your personal data is processed in compliance with GDPR and Data Protection Acts 1988 – 2018.	This app supports contact tracing while maintaining privacy. **Your identity will never be revealed to other app users.** The only personal data collected by the app is your IP address and your phone number, should you choose to share it with the HSE to receive a follow-up call for contact tracing. **No other personally identifiable information (e.g. GPS location) is gathered by the app.** Your personal data is processed in compliance with GDPR and Data Protection Acts 1988 – 2018. **Your personal data will never be used for any other purpose than to fight COVID-19.**
App Metrics	The HSE uses anonymous data about how people use this app in order to improve it and make the contact tracing process more effective. If you are happy to share anonymous data with the HSE about how you use the app please consent below.	The HSE uses anonymous data about how people use this app in order to improve it and make the contact tracing process more effective. **This information is gathered directly by the HSE and is not shared with third parties.** If you are happy to share anonymous data with the HSE about how you use the app please consent below. **This information cannot be used to identify you.**
Contact Tracing Follow-Up Call	If you are in close contact with a person infected with COVID-19 you will get an exposure notification on your phone.	If you are in close contact with a person infected with COVID-19 you will get an exposure notification on your phone.

	If you want we will try to call you to provide further assistance after you receive an exposure notification. You can enter your phone number below or add it in settings at a later stage.	If you want we will try to call you to provide further assistance after you receive an exposure notification. You can enter your phone number below or add it in settings at a later stage. **Your phone number will only be shared with the HSE if you get an exposure notification.**
COVID check-in	The COVID check-in lets you record how you're feeling every day. This anonymous information can only be accessed by the HSE, Department of Health and the Central Statistics Office. You can use this record if you are ever asked for a history of your symptoms. Along with your symptoms, you have the option to anonymously share your age range, sex and locality. This makes the data more useful for analysis because we will be able to see where COVID-19 is most prevalent, and what symptoms affect which groups most.	The COVID check-in lets you record how you're feeling every day. This anonymous information can only be accessed by the HSE, Department of Health and the Central Statistics Office. You can use this record if you are ever asked for a history of your symptoms. Along with your symptoms, you have the option to anonymously share your age range, sex and locality. This makes the data more useful for analysis because we will be able to see where COVID-19 is most prevalent, and what symptoms affect which groups most. **Any data you enter will remain anonymous and cannot be linked to you.**

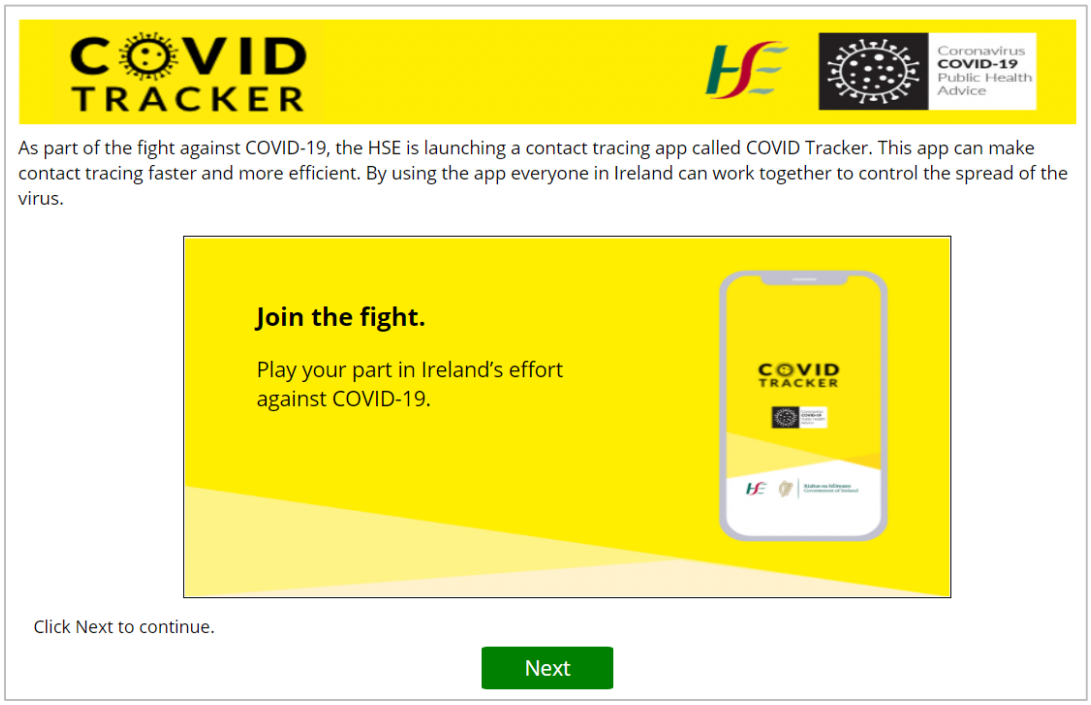
Goal-framing manipulations

Call-to-action page 1

"Safe progress" condition

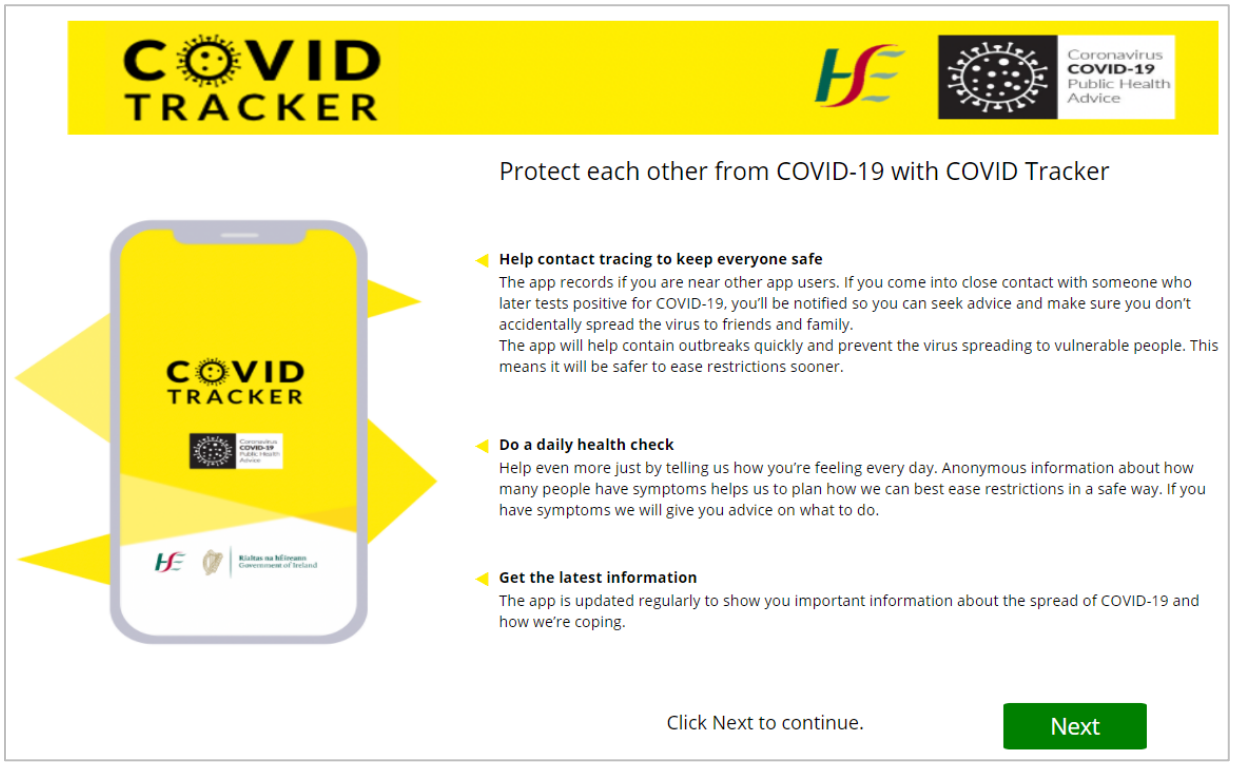


"Collective action" condition

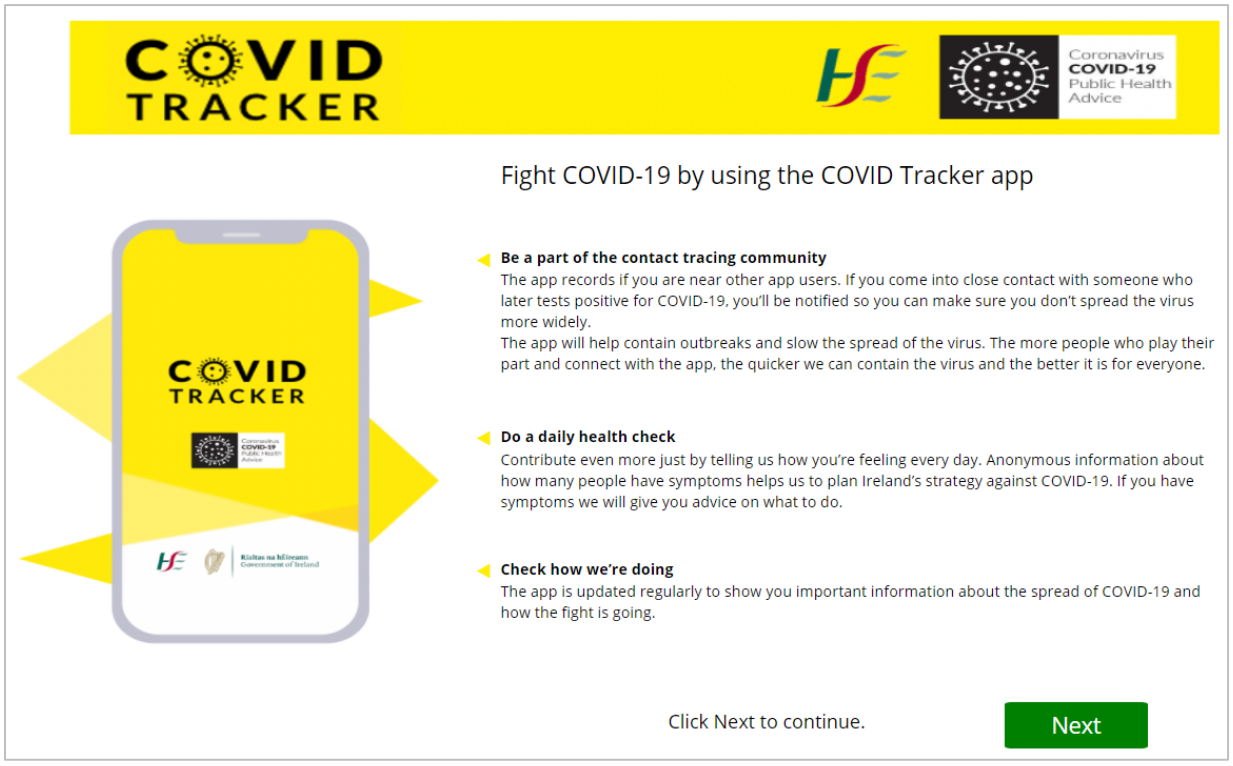


Call-to-action page 2

"Safe progress" condition



"Collective action" condition



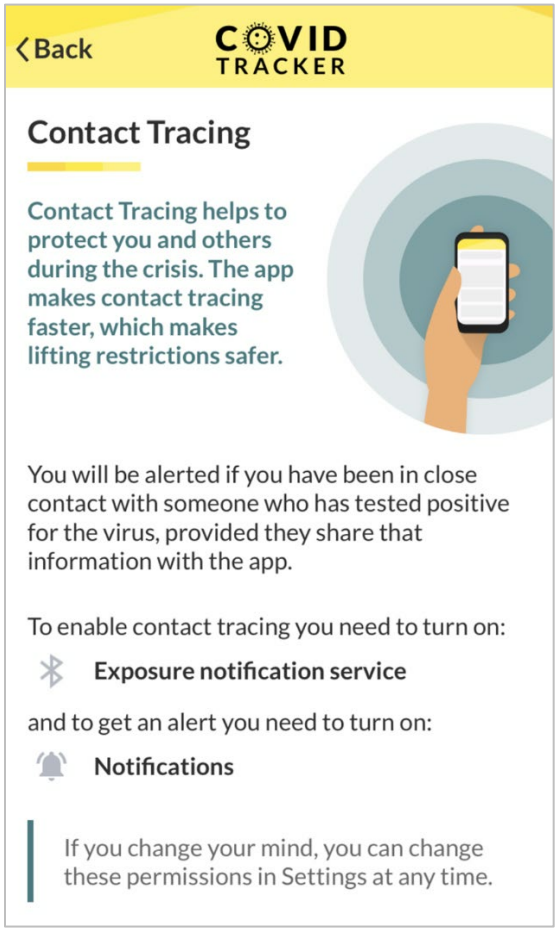
App - introductory screen

"Safe Progress" condition

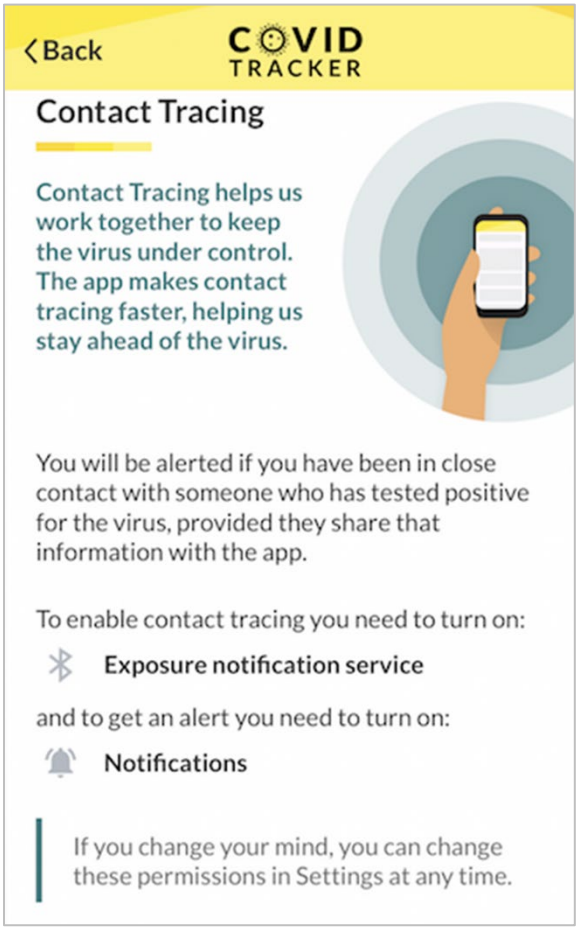
"Collective Action" condition

App - contact-tracing screen

"Safe Progress" condition



"Collective Action" condition



Exposure notification - (a) goal-framing & (b) structure manipulations

(a) "Safe Progress" (b) Control

(a) "Collective Action" (b) Intervention