Private Sector Regulation Increases Contact Tracing App Uptake: A Lesson for Vaccines and Digital Health Passports

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Abstract

COVID-19 contact tracing apps have not achieved targeted levels of uptake in the U.S.. We hypothesized that the promotion of contact tracing apps by private sector actors such as employers and retailers could increase uptake relative to current policies. We find empirical support for this hypothesis in an online experiment run on a representative sample of US adults. The increase in uptake expected from private sector policies is correlated with differential levels of confidence in the private and public sectors. What's more, private sector regulation enjoys more support than governmental app mandates. The novel option of using the private sector to promote contact tracing apps could offer important lessons for vaccination programs and vaccination passports.

Introduction

The U.S. has not achieved the level of uptake of digital contact tracing apps (DCTs) thought desirable for effective contact tracing [1,2]. We hypothesize that the private sector could play an important role in increasing DCT uptake. Our study measures the increase in DCT uptake that could be achieved by private sector policies that encourage or require the use of DCTs. We also study the role of confidence in government and in the private sector in explaining individual-level differences in uptake under different policies. Using a vignette study, we

measure likely differences in uptake under scenarios where employers or retailers require a DCT for entering their premises, as compared to the current government policy of voluntary use. Studying a representative sample of U.S. adults, we find evidence that private sector interventions could raise uptake. We also find evidence that private sector policies would be more widely supported than a government mandate. Enlisting the private sector could offer alternative and complementary mechanisms for pandemic mitigation.

To date, lack of confidence in government has posed a problem for DCT uptake in many countries. Altmann et al [3] in the U.S., Lockey et al [4] in Australia, and Munzert et al [5] in Germany all find that low levels of trust in government correlate with lower DCT uptake. This is important because levels of trust in government are at or near record lows in many countries, including in the U.S. and U.K. [6,7]. Due to this lack of confidence, governments face limits in their ability to promote DCT uptake.

There are few studies focusing on the role that the private sector can play in promoting DCT uptake given the current DCT regime, in which national or regional governments develop and release DCTs. The study closest to ours is that of Hargittai et al [8], who study the willingness of Americans to download a DCT released by any of eight distributors, including some private entities; a health insurer and a technology company. In Hargittai et al's study, a health insurer achieves one of the highest rates of uptake, but a technology company has one of the lowest rates. Romero and Young [9] also study private sector entities as distributors of DCTs. They find reluctance to share data with for-profit organizations in the context of DCT use. Available evidence thus suggests at best a mixed outlook regarding opportunities for the private sector to increase DCT uptake. Such evidence, however, is limited because previous studies have looked to the role of whether a public or private organization distributes an app. However, there is no

longer a need to explore this particular question because, under Apple and Google's policies, only governmental agencies can release a DCT app that can use technical features that enable seamless DCT functionality. See Apple [10].

Our study looks at the private sector promotion of an existing DCT created by the government. The design mirrors the current situation in the U.S. and other countries, in which governments have released DCTs, but have not taken significant steps to promote them. In the remainder of the paper, we present the hypotheses, design, and results of two randomized online experiments that address a potential role of the private sector to increase DCT uptake and to do so in a way that is supported by the general public. Our findings suggest that the private sector could play an important role in combating the pandemic due to some people's relatively higher confidence in businesses (as compared to their confidence in government). We conclude with a discussion of the implications of these results for other pandemic mitigation measures, including vaccine promotion and digital health passports.

Material and Methods

We present the results of two experiments. In the first experiment, we study the likely influence on uptake of various opportunities for private regulation of DCT use. In the second experiment, we study the likely support or opposition to such policies.

Experiment 1 Material and Methods

The primary question of interest in Experiment 1 is whether private sector policies can increase DCT uptake. We study the likelihood of downloading DCTs under four different scenarios: the "Voluntary" scenario captures the current policy under which app download is purely voluntary.

The “Retail Requirement” scenario assumes that retail stores require customers to download apps to be allowed to enter stores. The “Employer Encouragement” scenario assumes that employers strongly encourage employees to download the app. The “Employer Requirement” scenario assumes that employers require employees to download the app as a condition of employment.

Under each of these scenarios, participants were asked to indicate their likelihood of downloading on a seven-point Likert scale, from extremely unlikely to extremely likely. For example, in the Employer Encouragement condition, the prompt was as follows:

> *Imagine that the government asks that all residents voluntarily download the app to assist with contact tracing efforts. Also, your employer will now strongly encourage use of the app to enter the premises. Compliance will be encouraged by having an employee stand at the entrance of the premises to check app status. How likely are you to download the app under this policy?*

We measure uptake under three policies for each individual, with the ordering of policies counterbalanced. All participants see the Voluntary and Retail Requirement Policy, and participants were randomly assigned to either Employer Requirement or Employer Encouragement.

We also collect information regarding confidence in government and in the private sector with the following two prompts, each of which was also rated on a seven-point Likert scale.

> *How much confidence do you have in **the government** to act in the best interests of the public?*
>
> *How much confidence do you have in **businesses** to act in the best interests of the public?*

Finally, we collect other background information about attitudes towards privacy, technology, and politics. Demographic information is provided directly by the online polling platform and not by participants. The full vignette text, question text, and screen flow information are available in section 9 of the Appendix.

Data was collected via quota sampling on the Lucid Theorem polling platform and included n = 1,612 U.S. adults from a nationally representative sample stratified by age, race, and sex. Data collection took place in December 2020.

Experiment 2 Material and Methods

The second experiment measures the level of support for private sector DCT policies. We study support for a DCT requirement by an employer, by retailers, and by the government. We also measure willingness to download the app, willingness to wear a mask, and planned U.S. Presidential voting. In the Appendix, a flow chart shows the full experimental setup.

In the case of support, we measured this with the following question:

> *Employers could require that employees display their app status (green, orange, red) before entering their premises in order to protect other employees.*
>
> *How likely would you be to approve such policies?*

The full vignette text, question text, and screen flow information are available in section 10 of the Appendix.

The second experiment was conducted via quota sampling on an online platform and included 523 U.S. adults in a nationally representative sample stratified by age, race, and sex. Data collection took place in September 2020.

Results

Experiment 1: Responses to different regimes

We find that the differences in DCT uptake rates under the various regimes are quite small, with the rates varying between 47.4% and 51.0%, as shown in Figure 1, when responses from all participants are pooled. All variables and analyses are reported in terms of binarized indicators. All Likert scale indicators of 5 and above were converted to 1, and all else to 0.

Following our pre-registered hypotheses, we have analyzed the differences between the regimes, both using only the first responses and with all the responses pooled. All variables and analyses are reported in terms of binarized indicators. All Likert scale indicators of 5 and above were converted to 1, and all else to 0.

We first report differences between distinct regimes. In the pooled data, the differences are significant between Voluntary and Employer policies ($W = 3.597$, $p < .001$) and marginally significant between Retail and Employer policies ($W = 1.737$, $p = .08$). When only the first responses are used, we find that the differences are significant only between Employer and Retail policies ($W = 2.325$, $p < .05$). Statistical comparisons of all pairwise combinations are reported in section 1 of the Appendix for pre-registered hypotheses H1a and H1b.

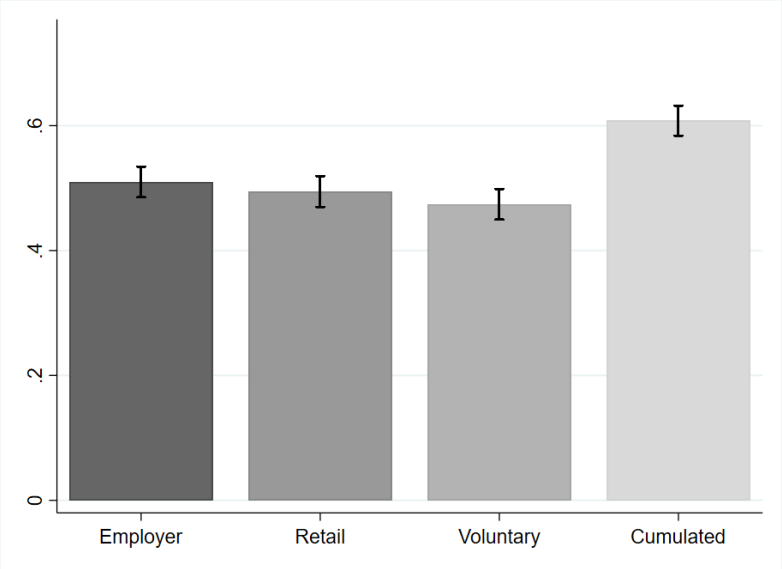

Fig. 1 Uptake rates under the three regimes in the study and in the cumulated regime are shown in the figure. They show a lack of large differences between diverse regimes but a significant difference between any individual regimes and a cumulated regime.

We next consider what download rates could be achieved under a cumulated regime in which all policies are presumed to be applied, here relying on within-subjects data. An individual is coded as positive for app download if they have indicated a likelihood to download under any of the regimes. Under a cumulated regime, DCT uptake moves from below 50% to 60.79% when transitioning from the current voluntary regime to a public-private cumulated regime, that is one that also includes private regulation. In the supplementary information we provide an analysis to show how this outcome differs from what would be expected merely from taking the maximum value where differences are only statistical noise rather than meaningful changes in preference. So while no individual policy can achieve a 10 percentage point increase relative to any other, the combination of policies could potentially do so.

Consistent with our pre-registered hypothesis, the higher rate is achieved because of differential preferences and differential uptake under different policies. For example, 16.6% of the respondents who would not download the app under a voluntary regime report that they would do so under a retail requirement regime. Only 37.8% report that they would download under all of the regimes. Further details of the within-subjects distribution of uptake is provided in the Appendix.

Experiment 1: Role of confidence in differential response

Consistent with Altmann et al [3], Lockey et al [4], and Munzert et al [5], greater confidence in the government is positively correlated with greater likelihood to download the app under the voluntary regime (coefficient = .124, 95% confidence interval = .114, .136, $p < .0001$) as well as under any of the other policies (see Appendix). Likewise, greater confidence in business is also positively correlated with likelihood to download the app under the voluntary regime (coefficient = .121, 95% confidence interval = .109, .134, $p < .0001$) as well as under any of the other policies (see Appendix). Thus, higher levels of confidence in government or businesses correlate with higher download likelihood in general (perhaps in part because confidence in government and confidence in business show a correlation of .70).

A majority of the participants (53.6%) show a differential between confidence in government and in businesses. These subpopulations identified by different relative confidence levels in government and in businesses have a significant presence in the participant pool, with 38.2% of participants expressing more confidence in businesses than in government, and 15.5% the reverse. Of those who have more confidence in business, the modal confidence in government is 1 and the modal confidence in business is 4. Of those who have more confidence in government, the modal confidence in government is 5, and the modal confidence in business is 4.

Fig. 2 People who have more confidence in businesses are more likely to download a DCT under an employer regime than under a voluntary regime. No such effect appears for those who have more confidence in government.

As shown in Figure 2, differentials in confidence correlate with different download rates under the Voluntary or Employer policy. People who have more confidence in businesses are more likely to download a DCT under an employer regime than under a voluntary regime (47.7% vs 39.9%). No such effect appears for those who have more confidence in government (61.0% vs 61.4%). In a post hoc analysis, we find a significant difference in uptake between a voluntary or employer regime for those who have more confidence in businesses (Wilcoxon sign rank test yields $W = 3.77$ and $p < .001$) but not for those who trust government more ($W = .15$ and $p = .88$).

Experiment 2

In the first experiment, we find support for the hypothesis that DCT downloads would be higher with private sector regulation. However, policies can only be effective if private sector entities are able to deploy the policies without strongly negative reactions. We next study whether there would be support for such policies.

Experiment 2 : Support for different regimes

DCT requirements from retail businesses ($W = 6.11$, $p < .0001$) or employers ($W = 8.66$, $p < .0001$) receive significantly more support than a mandate coming from the government, as seen in Figure 3. The shift in support from the government mandate to the most popular private sector policy, the employer requirement, is 18.7 percentage points.

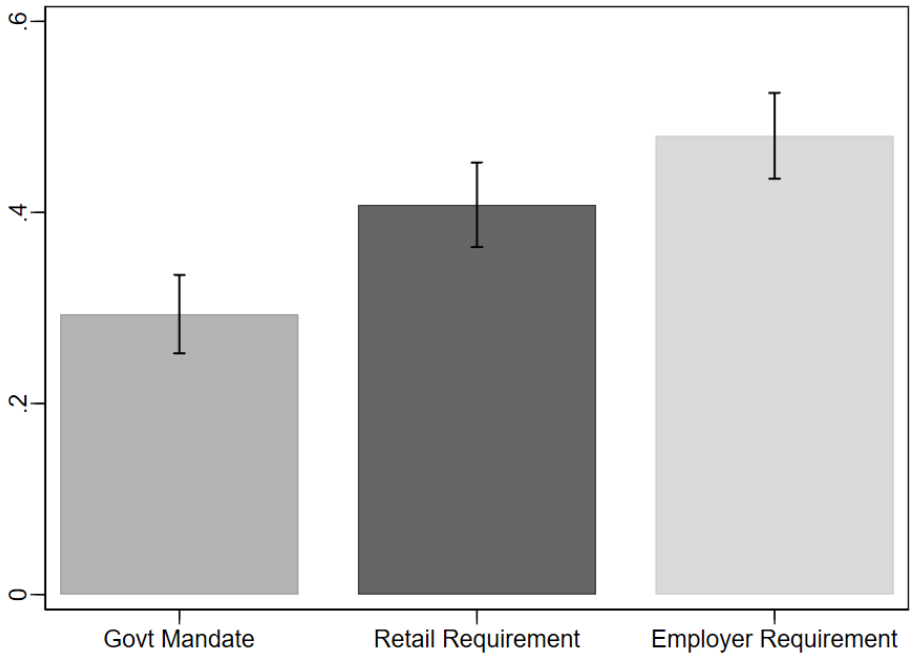

Fig. 3 Support for a government DCT mandate is far less than support for a retail requirement or an employer DCT regime.

As with uptake, there is also an increase in cumulated support (defined in the same way as previously described for uptake) relative to the most popular policy standing on its own. Thus, support for the DCT promotion policies also reflects varying within-subject preferences for the public as compared to private initiatives, just as is the case for DCT download decisions.

Experiment 2: Polarization on pandemic-mitigation measures

Planned U.S. presidential voting shows a strong bifurcation in support for mask mandates but a far smaller bifurcation in response to DCT uptake. The difference between Biden and Trump voters is statistically significant for both masks ($W = 8.96$, $p < .001$) and DCTs ($W = 4.34$, $p < .001$). However, as shown in Figure 4, the gap is far smaller in the case of DCTs, at 11 percentage points as compared to 35 percentage points for masks. These findings are similar to but distinct from Zhang et al [11], who report that Democrats and Republicans showed similar levels of support (46% and 47% respectively) for the government to encourage use of DCTs despite partisan differences with respect to other surveillance measures.

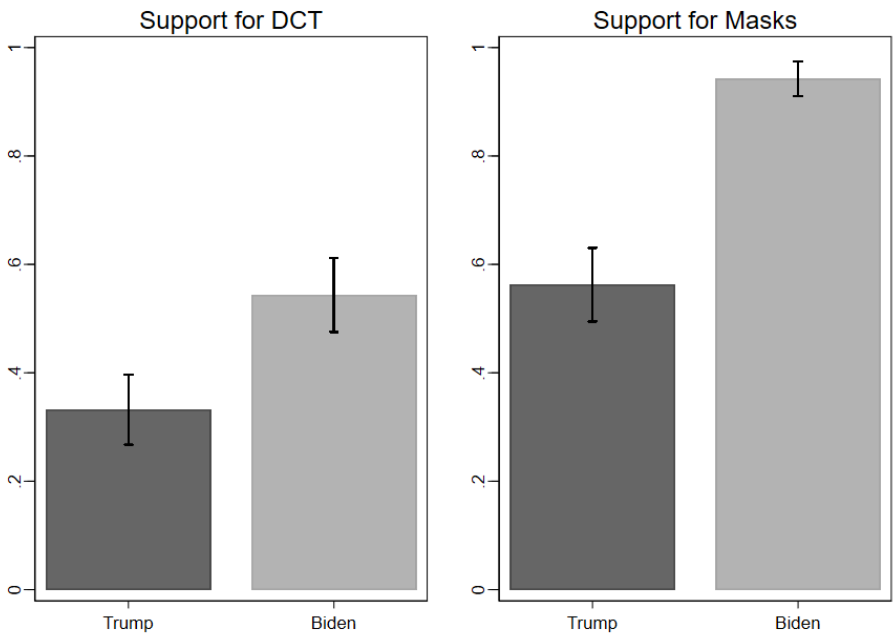

Fig. 4 The U.S. political partisan gap in support for mask mandates is larger than the partisan gap in support for DCTs.

Discussion

Using two experiments collected from nationally representative samples of 1,612 and 523 respondents respectively, we reveal key findings for policymakers and private-sector stakeholders. Significantly more Americans would download DCTs under a private sector policy than under the current policies. Surprisingly, private sector policies are equally effective whether framed as a requirement or as encouragement, suggesting that private sector pandemic mitigation might be effective even if the contemplated private sector policies are not very intrusive. This is mainly driven by those participants who report relatively little confidence in government as compared to confidence in business. Finally, a majority of Americans would support such private sector policies, which would not be the case for a government mandate.

There are important limitations when considering how to translate results from this study to likely impact in the real world. Our design methodology cannot replicate a real-world decision of whether to download and continue use of a DCT. Although vignette studies can be a good prediction of behavior [12], DCT download decisions could be highly context-dependent. We thus place more faith in our result that private sector engagement increases app uptake than in the absolute values of our uptake estimates.

We identify a large minority in the population who have more confidence in businesses than in government and who behave qualitatively differently with respect to DCT uptake. For those who have more confidence in businesses, private sector policies can be a crucial tool to increase DCT uptake. Our result therefore shows how governments can close a confidence gap for a numerically important segment of the population by leveraging the comparatively higher confidence in the private sector. This is particularly important because, for this segment of the population, confidence in government is so low that it's not clear the government can otherwise affect the actions or beliefs of such individuals.

We also find that support for DCTs appears far less polarized than support for masks, possibly because the former is far less politicized. This suggests a cost of politicization for effective pandemic mitigation. Vaccine passports, which would enable the private sector to enact policies aimed at overcoming vaccine hesitancy, are increasingly getting caught up in the fissures of a culture war and may ultimately face the same politicization cost as masks.

Conclusion

An effective DCT regime likely needs to promote app uptake but also obtain public support. The public-private options explored here have identified a promising path forward to promote DCT

uptake in the U.S. and likely more widely, such as in other countries and for other pandemic mitigation measures. As countries around the world have discovered during Covid-19 vaccination rollouts, most parts of the world include large portions of people who do not want to be vaccinated [13]. Many similar patterns to DCT resistance are replicating in vaccine resistance, including the importance of trust in government [14] and the threat of political polarization [15] in vaccination uptake. Consistent with Lee et al [16], we show that private entities can help fill the confidence gap that is partly responsible for resistance to vaccination. Governments should thus consider options to directly coordinate with the private sector or to empower the private sector to enact the private sector policies studied here.

In assessing the current state of DCTs, we recognize that many countries and regional governments already appear to have given up on DCTs. For example, de la Garza [17] cites a lack of coordination by the U.S. federal government and a lack of advertisement funding as two reasons that digital contact tracing has not succeeded. However, even if governments do not pursue campaigns to increase DCT uptake, our results are relevant for COVID-19 mitigation, particularly with respect to vaccination and digital health passports. The patterns of resistance to DCTs are similar to that of resistance to vaccination. Additionally, as with DCT uptake, the rate of uptake for vaccination has to reach a critical threshold in order to offer desirable levels of protection for all members of society. Likewise, digital health passports can only be useful to the degree that they are largely accepted and adapted.

There are already some recent examples of measures supported by this research with respect to vaccination policy. Consider that the U.S. Equal Employment Opportunity Commission issued guidelines to clarify that employers can legally require COVID-19 vaccination (U.S. Equal Employment Opportunity Commission [18], easing potential legal concerns that private entities

might otherwise have about imposing vaccine requirements. Another example of the government enabling or easing the possibility of private regulation is New York State's launch of an app that allows people to show they have been vaccinated against COVID-19 or that they have recently tested negative [19].

In a different vein, employers can also proactively take steps to assist government policies. For example, some private employers have enacted policies such as paid time off to receive a vaccination [20]. Our research suggests that such policies will be particularly effective to supplement existing government campaigns due to differential responses in a heterogeneous population where some individuals are driven by their low confidence in government and comparatively high confidence in business.

Our research suggests that government measures that restrict the ability of the private sector to promote COVID-19 mitigation technologies, such as Florida's governor banning businesses from requiring vaccine passports [21], foreclose a promising option to enhance pandemic mitigation tool uptake. We also find strong evidence that a private sector option for enforcement is particularly important for people who trust businesses more than they trust government. Thus, such policies that ban private sector enforcement are worrying in that they foreclose a viable and effective opportunity to increase uptake of pandemic mitigation technologies among a numerically important segment of the population.

In conclusion, we find evidence to support private sector initiatives to encourage pandemic mitigation measures where a lack of confidence in government has otherwise proven to be a significant barrier. This evidence should be factored into pandemic mitigation strategies so as to increase uptake for a variety of crucial measures that will allow pre-pandemic patterns of life to resume.

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Appendices

Extended Methods

Consent and ethics

Both studies were pre-registered before data collection (https://osf.io/qgahu/). Our research complies with the General Data Protection Regulation as well as analogous Swiss data protection law. The data were collected, analyzed by the researchers, and made available in anonymous format with informed consent from the participants.

Sample size

We pre-registered our sample size calculations at Open Science (https://osf.io/qgahu/).

For the first experiment, we estimated the required sample sizes on the basis of resampling simulations using pilot data. Random samples from the pilot data were resampled with replacement with increasing sample sizes from 150 to 3000, on which our proposed hypotheses were tested. These simulations indicate that a sample size n=1600 provides sufficient power (80%) to find significant effects for our proposed tests.

Likewise, we applied the same sample size calculations for the second experiment. However, we report only a portion of our results for the second experiment. The full experiment included a 2x2 factorial design, while we here report only the results for one specific cell of treatment. Full results are reported in another manuscript and available upon reasonable request from the authors. In this case, our analyses suggested a sample size of n = 1800 for the full experiment, and ¼ of those data points are reported here. The outcomes of the analyses here are not different when including all participants rather than for the subset of participants of interest here.

Subject recruitment

The study was posted on Lucid Theorem's online polling platform. Quota sampling was conducted to create a nationally representative sample on the basis of gender, ethnicity, and age. The sample statistics reported throughout include only participants who completed the study.

	Number who began study	Number who completed the study	Completion rate
Experiment 1	1,985	1,612	81.2%
Experiment 2	1,900	523	27.5%

Not all participants completed the survey. The completion rate for Experiment 2 is potentially problematic insofar as it suggests potential sampling effects. We believe the high dropout rate is attributable to the experimental design choice to force a minimum time spent on the vignette screens combined with mandatory passing of all comprehension questions. This could result in several additional minutes spent to complete the experiment in the event of not answering the comprehension questions correctly on the first attempt.

However, we do not believe any sampling effects were significant with respect to the main quantities of interest, as the relative support levels for different policies mirrored those we saw in our pilot data, which did not include such high rates of dropout due to not including the minimum required reading time.

Procedural Details

Experiment 1: After consenting to participate in the experiment, participants read a brief description to describe DCTs and imagine that their government has adopted such a tool. The information was presented on two separate pages, with the first, longer page requiring 30 seconds before participants could navigate forward, and the second, shorter page requiring 15 seconds before participants could navigate forward. Participants were then asked a series of questions, all measured on a 7-point Likert, regarding their likelihood of downloading the app under the different scenarios. They were also asked about their likelihood to take actions with respect to entities who required the app (retailers and employers). Then participants were asked about their confidence in government and in businesses, and finally they were asked questions about privacy, technology, and their U.S. presidential voting.

Experiment 2: After consenting to participate in the experiment, participants read a brief description to describe DCTs and imagine that their government has adopted such a tool. The information was presented on two separate pages, and each page required the participant to stay on the page for at least 90 seconds before the button to navigate forward became available. Participants faced three control questions on the definition of a centralized DCT system, the relative surveillance value of the centralized and decentralized architectures, and the utility of the two architectures for public health officials. Participants were then asked their likelihood to download the app. Next, they answered questions about support for various private or government actors requiring their apps and also about their support for laws preventing such requirements. Finally, they were asked about their political views, privacy attitudes, and support for a mask mandate. All measures were taken on a 7-point Likert scale.

For both experiments, the full series of text, including screen apportionment and the wording of questions, is available in the preregistration document https://osf.io/qgahu/ as well as in the Appendix.

Measurement

All but two reported measures correspond directly to a question in the experiment and can be seen directly in the vignette screen flows provided in the preregistrations (https://osf.io/qgahu/).

"Cumulated" measures: The two measures that do not correspond directly to a question in the experiment are those reported as "cumulative uptake" and "cumulative support". Cumulative uptake is the maximum Likert-scale value reported by the subject for app uptake under any of the three scenarios (voluntary, retail policy, or employer policy) in Experiment 1. Cumulative support is the same measure for support indicators in Experiment 2.

"App uptake": App uptake as discussed in this article is measured as stated likelihood to download the app on a 7-point Likert scale. Binary app uptake were derived by coding any Likert-scale responses of 5, 6, or 7 as app uptake. Thus the midpoint, the point of neutrality, was considered as a negative response, so as to keep the app uptake indicator more conservative with respect to download intent.

Analytical methods

All analyses presented were pre-registered unless explicitly identified as post hoc analyses. Our analysis is also laid out with respect to each pre-registered hypothesis in the supplementary information for ease of checking results against the pre-registered hypotheses.

Wilcoxon rank-sum tests and t-tests were used to assess differences between populations in uptake and support for the policies studied, consistent with the pre-registered hypotheses.
Ordinary least-squares regression was applied in the case of regression analyses.

We have constructed the "cumulated" scores by taking the maximum value given by each respondent among all three regimes, with the assumption that, had all three options been available, he or she would have given the same responses, and that we can take this composite score as if it is singly drawn from each respondent, rather than a constructed measure. Then we compare the "cumulated" scores to the uptake willingness under each regime. We recognize that this is not a formally correct approach to analyze this statistically, as we are comparing a constructed variable against its components. Nevertheless, Wicoxon rank-sum tests and t-tests show that the uptake under the combined regime would be notably higher than under any single regime.
In addition, we address the question of question order effect by explicitly incorporating the balanced within-subject design of the experiment in our post hoc data exploration, as detailed in the supplementary information by systematically analyzing the changes in responses across different regimes. By the design of the experiment, the changes from one regime to another at every step is matched by nearly exactly the same changes in the opposite direction.. This does not suggest ordering effects apart from the case of uptake under a retail requirement,

Data Availability

Anonymized versions of the datasets are available at https://osf.io/qgahu/. Data from the pilot studies are also available via the same URL.

Code Availability

All data analysis was conducted with Stata 15.1. The Stata code to reproduce all reported analyses is available at https://osf.io/qgahu/.

Extended Data

Figure 1 summary data

Group	**Mean**	**Standard Deviation**
Voluntary	.474	.499
Retail	.494	.500
Employer	.510	.500

	Retail Requirement		**Employer**	
	W	**p**	**W**	**p**
Voluntary	1.163	.245	.635	.525
Retail Requirement			1.798	.072

Figure 2 summary data

Confidence	**Policy**	**Mean**	**Standard Deviation**

More Confidence in Business	Voluntary	.399	.490
More Confidence in Business	Employer	.467	.499
More Confidence in Government	Voluntary	.610	.489
More Confidence in Government	Employer	.614	.488

Figure 3 summary data

Group	**Mean**	**Standard Deviation**
Gov't Mandate	.294	.456
Retail Requirement	.408	.492
Employer Requirement	.480	.500

Figure 4 summary data

Voting	**Policy**	**Mean**	**Standard Deviation**
Trump	DCT	.332	.472
Biden	DCT	.543	.499
Trump	Masks	.563	.497
Biden	Masks	.942	.234

Appendix

Contents

1. Analysis for all pre-registered hypotheses.

Hypotheses were pre-registered at Open Science (https://osf.io/qgahu/).

1. Analysis for all pre-registered hypotheses.

H1a: The app uptake rate on the first response will be different between the populations assigned to each pair of the regimes, as tested by t-test and Wilcoxon rank sum test.

H1b: The average respondent will vary in the responses with regards the uptake rate when faced with multiple scenarios in sequence, as tested by both a t-test and a Wilcoxon sign rank test.

H2a: People who are more trustful of the government unconditionally are more likely to download the app under a voluntary regime than people who trust the government less. (as tested by a linear regression)

H2b: People who are more trustful of the government relative to the businesses are more likely to download the app under a voluntary regime compared to the employer regime than people who trust the government less. (as tested by a linear regression with interactions)

H4: Privacy attitudes are predictive of download rates: people who care more about their privacy are less likely to download the app under each of the scenarios. (as tested by linear regression)

H5: The likelihood to download between those responding to an employer requirement and those responding to a strong employer suggestion will not be

statistically different. (To be tested by two one-sided t-tests with a medium effect size)

2. Heterogeneous uptake and support for public and private policies

3. Between-subjects data on DCT uptakes under different regimes

4. Distribution Reporting for Differential Uptake According to Differential Trust

5. Statistical Reporting of Different Responses to Different Policies for those with Less Confidence in Business than in Government

6. Cumulated Uptake Modeling

7. Political polarization results for entire subject pool of Experiment 2

8. Distribution of Confidence in Businesses and Government among Those Who Trust Businesses More vs. Those Who Trust Government More.

9. Full text of Experiment 1

10. Full text of Experiment 2

H1a: The app uptake rate on the first response will be different between the populations assigned to each pair of the regimes, as tested by t-test and Wilcoxon rank sum test.

	Mean	**N**	**Retail Requirement**		**Employer**	
			W	**p**	**W**	**p**
Voluntary	.461	518	1.150	.250	1.147	.251
Retail Requirement	.426	535			2.325	.020
Employer	.496	556				

	Mean	**N**	**Retail Requirement**		**Employer**	
			t	**p**	**t**	**p**
Voluntary	.4613 .89	518	1.150	.251	1.147	.252
Retail Requirement	.4263 .85	535			2.330	.020
Employer	.4964 .12	55618				

H1b: The average respondent will vary in the responses with regards the uptake rate when faced with multiple scenarios in sequence, as tested by both a t-test and a Wilcoxon sign rank test.

	Mean	**N**	**Retail Requirement**		**Employer**	
			W	**p**	**W**	**p**
Voluntary	.474	1,612	2.091	.04	3.597	<.001
Retail Requirement	.494	1,612			1.737	.08
Employer	5.10	1609				

H2a: People who are more trustful of the government unconditionally are more likely to download the app under a voluntary regime than people who trust the government less. (as tested by a linear regression)

results from here

Linear regression of voluntary download on confidence in government

	Coefficient	**Standard Error**	**95% Confidence**	**p**

			Interval	
Trust in Government	.125	.006	.114 .136	<.0001

H2b: People who are more trustful of the government relative to the businesses are more likely to download the app under a voluntary regime compared to the employer regime than people who trust the government less. (as tested by a linear regression with interactions)

Simple regression of willingness to download under voluntary regime on trust differential

	Coefficient	**Standard Error**	**95% Confidence Interval**	**p**
Trust in government - Trust in business (difference in trust)	.05	.009	.029 .063	<.0001

Regressing likelihood to download (under any regime) on trust differential, using the employer regime as the baseline.

	Coefficient	**Standard Error**	**95% Confidence Interval**	**p**
Trust in government - Trust in business (difference in trust)	.034	.014	.006, .062	<.05
Retail regime	-.066	.031	-.127, -.004	<.05
Voluntary Regime	-.026	.032	-.089, .037	.419
Difference in trust * retail regime	.014	.021	-.027, .055	.497
Difference in trust * voluntary regime	.012	.021	-.028, .053	.557

H3: People who are more trustful of businesses unconditionally are more likely to download the app under a private sector initiative than people who trust businesses less. (as tested by a linear regression)

Uptake Predicted under Which Regime	**Predictor**	**Coefficient**	**Standard Error**	**95% Confidence Interval**	**p**
Retail Requirement	Confidence in business	.116	.006	.103, .128	<.0001
Employer	Confidence in business	.110	.006	.097, .123	<.0001

H4: Privacy attitudes are predictive of download rates: people who care more about their privacy are less likely to download the app under each of the scenarios. (as tested by linear regression)

Linear regression of general privacy indicator on uptake under each treatment

	Coefficient	Standard Error	95% Confidence Interval	p
Voluntary	-.02	.01	-.043, -.003	.03
Retail	-.02	.01	-.043, -.002	.03
Employer	-.02	.01	-.041, -.002	.05

Linear regression of COVID-19 privacy indicator on uptake under each treatment

	Coefficient	**Standard Error**	**95% Confidence Interval**	**p**
Voluntary	.05	.01	.041, .068	<.0001
Retail	.04	.01	.031, .058	<.0001
Employer	.044	.01	.030, .057	<.0001

H5: The likelihood to download between those responding to an employer requirement and those responding to a strong employer suggestion will not be statistically different. (To be tested by two one-sided t-tests with a medium effect size)

We conduct a two-one sided t-test analysis (TOST) to compare the Employer Requirement and Employer Encouragement conditions. We find that under the pre-registered medium effect size, these treatments are not equivalent (TOST analysis, Cohen's d = .08, 95% confidence interval = (,-.02, .17), $p < .0001$).

2. Heterogeneous uptake and support for public and private policies

		Retail requirement			
		No		**Yes**	
Voluntary Regime		**Employer**		**Employer**	
		No	**Yes**	**No**	**Yes**
	No	39.28%	4.66%	3.23%	5.53%
	Yes	3.60%	3.11%	2.92%	37.66%

Table A large minority of participants from the first experiment would not download the app under any policy (39.28%) while another large minority would download the app under any of the policies (37.66%). These figures are underlined in the table. This leaves a final minority of 23.06% who are differentially responsive to the private sector policies.

		Retail requirement			
		No		Yes	
Gov't Mandate		**Employer requirement**		**Employer requirement**	
		No	**Yes**	**No**	**Yes**
	No	46.12%	10.27%	3.77%	10.48%
	Yes	1.26%	1.47%	0.63%	26.00%

Table 46.12% of participants in the second experiment indicate no support of any of the proposed policies.

This leaves a majority who do support at least one of the policies.

3. Between-subjects data on DCT uptakes under different regimes

We find that DCT uptake rates under the various regimes are similar, varying between 42.6.% and 49.6% in their first responses, as shown in Figure A1. Consistent with our pre-registered hypotheses,[1] we analyze data on a between-subjects basis and find a significant difference only between the Employer and Retail Requirement regimes ($W = 2.325$, $p < .05$) For other pairs of policies, there is no significant difference.[2]

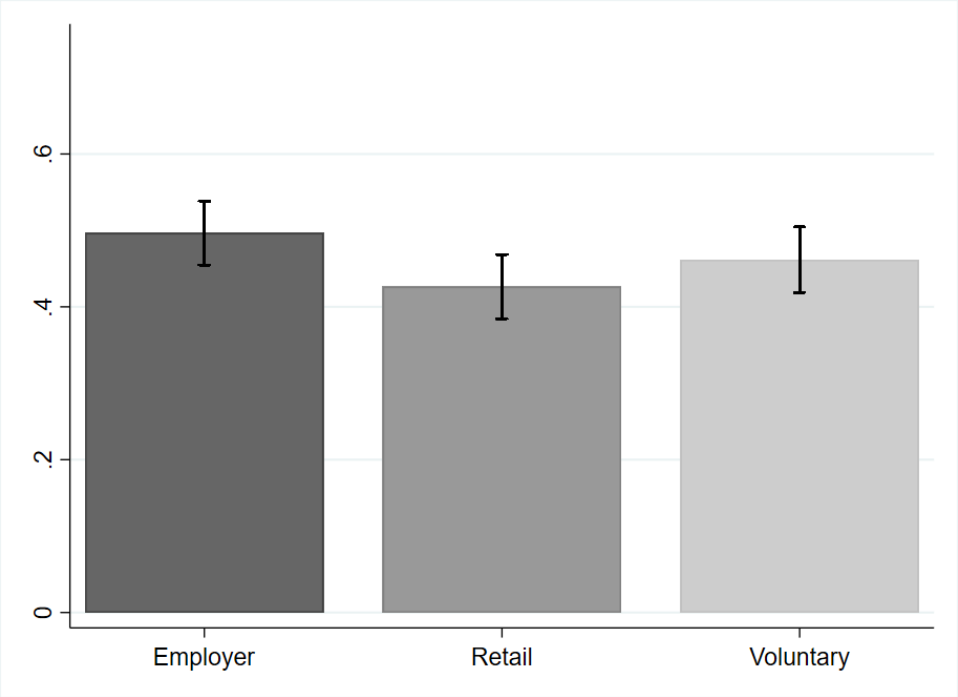


Figure Uptake rates under the three regimes in the study

[1] Explicit analysis pertaining to each pre-registered hypothesis is reported in the Appendix.
[2] Statistical comparisons of all pairwise combinations are reported in the Appendix.

Group	Mean	Standard Deviation
Voluntary	.461	.499
Retail	.426	.495
Employer	.496	.500

Table Summary data for figure

4. Distribution Reporting for Differential Uptake According to Differential Trust

We tabulate the uptake under all three regimes in Table A1 for these two subpopulations identified according to their relative trust in business and in government. Those who have more confidence in business than in government exhibit significantly different response rates under the three regimes (see Appendix for statistical reporting), while there is no significant variation under the three regimes for those who have more confidence in government.

Uptake Rate	Employer	Retail	Voluntary
More Confidence in Business	46.7%	43.2%	39.9%

More Confidence in Government	61.0%	63.5%	61.4%

Table A1 Uptake varies under the regimes for those who have more confidence in business but not for those who have more confidence in government.

5. Statistical Reporting of Different Responses to Different Policies for those with Less Confidence in Business than in Government

	Retail	Voluntary
Employer	Z = 2.157 P=.03	Z = 3.772 P<.001
Retail		Z = 1.873 P=.06

*Comparison table for the subset with more confidence in business only.

6. Cumulated Uptake Modeling

For each participant we have three uptake decisions (Voluntary, Retail, Employment). We convert these decisions to three data points, those being the differences between the uptake decisions under each combination of policies. Also, each uptake decision is binarized ("would"/"would not" download, with "would not" including the midpoint of 4 on the 7 point Likert scale).

We have rearranged the data so that the dependent variable is the change in the respondents' response and the main dependent variable is the change in regime. In other words, we code the change in response as -1 if the respondent first sees the voluntary only regime answered that he would download, but he would not under the employer regime which he sees later, for the regime change voluntary -> employer. For the changes in the opposite direction, i.e. someone who sees the employer regime first and voluntary regime later, we reverse the signs, i.e. we code as 1 someone who first responds that he would download (i.e. under employer regime) and later responds that he would not (under voluntary regime).

In each case we calculate the regime change as later response minus earlier response. However, to combine policies that went in opposite directions, we invert the sign of the response to convert it to a unified direction. This results in the following pattern

Binary change	Voluntary -> Employer	Voluntary -> Retail	Retail -> Employer
Yes -> No	6.53%	6.71%	6.15%
No Change	83.28%	84.52%	84.63%
No -> Yes	10.19%	8.76%	8.91%

Table Distribution summary of binarized response differences under different regime transitions

While the high percentage of binary change of 0 seems to suggest that most participants are stable in their uptake assessments, as we have shown in detailed tables in the appendix, the uptake decisions are in fact varying in many combinations.

Another potential critique of our assertion that a cumulated regime makes a difference is that part of this additional uptake could reflect a demand effect. In our experiment, we ask participants three questions in a row about downloading the same DCT under different scenarios. It is possible that they ultimately opt to a yes simply due to the repetition of similar questions, and the slight tilt of the distribution shown in the table above could reflect such a demand effect. However, we posit that the results are not only the result of a demand effect but rather due to differential responses to different regimes for those with more trust in business than in government.

We test this hypothesis with a regression analysis. We look to evaluate the effect of a difference in confidence in the private and public sectors. We regress the binary change variable on our difference in confidence variable and the change type (corresponding to each of the three columns in the table above), with clustered standard errors around each participant.. The

baseline category is voluntary -> employer regime. Standard errors are clustered around each respondent id. For each respondent, there are three observations, one for each of the 3 possible regime changes.

Variable	**Coefficient**	**Standard Error**	**95% Confidence Interval**	**p**
Voluntary -> Retail	-.011	.015	-.039, .018	.468
Retail -> Employer	-.018	.015	-.047, .010	.214
Difference in trust	-.017	.007	-.030, .004	<.05
Difference in trust * Voluntary -> Retail	.012	.010	-.007, .031	.217
Difference in trust * Retail -> Employer	.005	.010	-.014, .024	.590

Table Regression coefficients suggest explanatory power of difference in confidence for response heterogeneity

The coefficients on the variable difference in trust cannot be interpreted directly because it is the sum of the main effect and the interaction effect, of which the latter is a function of the value of the difference in trust. We need to examine the marginal effects to discern how participants with varying levels of confidence in government and businesses respond to the changes in treatments. To compare those who expressed more confidence in businesses than government and vice versa, we calculate the marginal effects at their respective means, (M = -1.89 and 1.57 respectively, with negative values indicating more trust in business)

Variable	**Margin**	**Standard Error**	**95% Confidence Interval**	**p (with Bonferroni correction)**
Voluntary -> Employer	.061	.015	.020, .101	<.001
Voluntary -> Retail	.028	.014	-.006, .062	.155
Retail -> Employer	.033	.014	.000; .066	<.05

Table Marginals for mean value for those with more confidence in business

Variable	Margin	Standard Error	95% Confidence Interval	p (with Bonferroni correction)
Voluntary -> Employer	-.002	.017	-.039, .043	1.0
Voluntary -> Retail	.010	.016	-.029, .049	1.0
Retail -> Employer	-.008	.016	-.046, .030	1.0

Table Marginals for mean value for those with more confidence in government

The difference is striking: there are significant differences for various regime changes for those who trust businesses more than government, even after applying Bonferroni correction. The change between voluntary and employer regime, in particular, is both substantial and robust. In contrast, there is hardly any change between the regimes for those who trust government more than businesses. This variation is important as far larger share of the population at large have greater confidence in businesses than government (38.2% vs. 15.5% in our sample)

7. Political polarization results for entire subject pool of Experiment 2

Planned U.S. presidential voting shows a strong bifurcation in support for mask mandates but a far smaller bifurcation in response to DCT uptake. The difference between Biden and Trump voters is statistically significant for both masks ($W = 16.34$, $p < .001$) and DCTs ($W = 4.34$, $p < .001$).[3] However, as shown in the figure below, the gap is far smaller in the case of DCTs, at 11 percentage points as compared to 35 percentage points for masks.

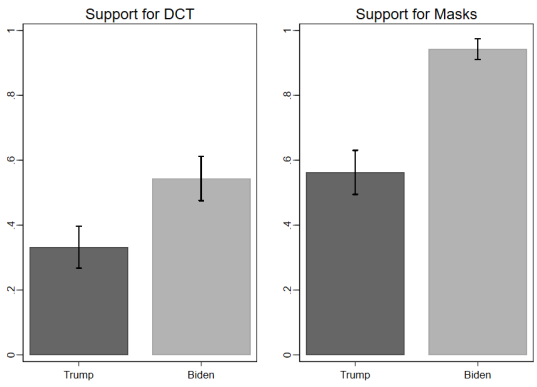


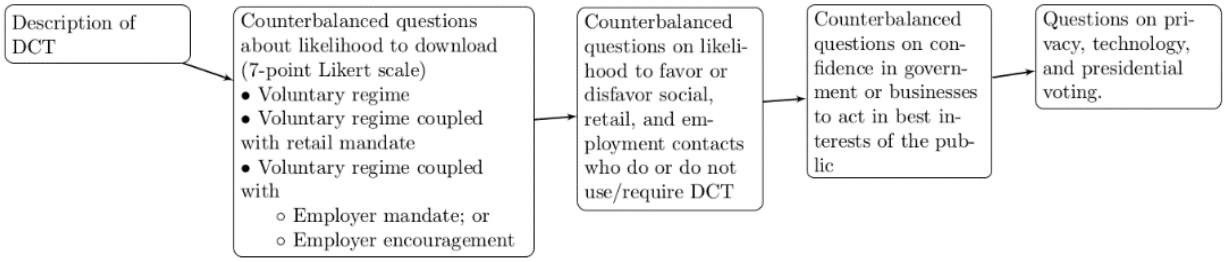
Figure The partisan gap in support for mask mandates is larger than the partisan gap in support for DCTs.

[3] Zhang et al (2020) report similar findings that Democrats and Republicans showed similar levels of support (46% and 47% respectively) for the government to encourage use of DCTs despite partisan differences with respect to other surveillance measures.

8. Distribution of Confidence in Businesses and Government among Those Who Trust Businesses More vs. Those Who Trust Government More.

Figure Distributions of Confidences in Government and Businesses

9. Full text of Experiment 1



[SCREEN]

The government is looking for ways to minimize the spread of COVID-19. In order to do so and to ease lockdowns, it announced the launch of a new app that will enable widespread contact tracing.

Contact tracing is the process of notifying all recent contacts of a person who tested positive for the virus. These recent contacts can then self-isolate and possibly get tested for the virus.

So far, contact tracing has mainly been done by public health workers. The new app will use technology to make this process more efficient and allow nationwide tracing.

The app records people's in-person encounters. If someone tests positive for COVID-19, the app indicates which other app users might also have been infected.

As a user, the app would constantly show you whether your exposure status is green, orange, or red. Green indicates that you were almost certainly not in contact with an infected person. Red means that there's a high likelihood you have been infected. Orange means that there is some lower likelihood you are infected.

The app relies on your phone's Bluetooth connection and calculates likelihood of infection based on the proximity and duration of an encounter with an infected person. For this to work, both the infected person and the potential contact must have the app on their phones. Developers believe that the app will work well in predicting infections provided that about 60% of the population downloads it.

[SCREEN]

Centralized vs. Decentralized Systems

There is an ongoing debate among researchers and health officials about whether contact tracing apps should follow a centralized or decentralized system.

A decentralized contact tracing system means that information about your contacts is only stored locally on your phone. In other words, you have full control over your information. A centralized contact tracing system means that a single server stores all tracing data. Any information-sharing among phones in a centralized system goes through this central server.

Decentralized contact tracing apps are considered more protective of users' privacy than centralized contact tracing apps. A centralized system offers more potential for governmental misuse of the collected data: Governments would have access to considerable troves of data about people's contacts, including who the user met at any time, where, and for how long. This data could potentially be used for purposes unrelated to COVID-19, such as surveillance and law enforcement.

[SCREEN]

The government will launch a decentralized app soon.

[SCREEN]

We are now going to ask you a few questions...

(next three (ABC) have varied ordering)

[SCREEN A]

Imagine that the government asks that all residents voluntarily download the app to assist with contact tracing efforts. Also, businesses you patronize will now require use of the app to enter the premises. Compliance will be monitored by having an employee stand at the entrance of the premises to check app status, and those without the app will not be permitted to enter. How likely are you to download the app under this policy?
(7 point Likert scale)

[SCREEN B]

Imagine that the government asks that all residents voluntarily download the app to assist with contact tracing efforts. How likely are you to download the app under this policy?
(7 point Likert scale)

[SCREEN C]

Imagine that the government asks that all residents voluntarily download the app to assist with contact tracing efforts. Also, your employer will now strongly encourage use of the app to enter the premises. Compliance will be encouraged by having an employee stand at the entrance of the premises to check app status. How likely are you to download the app under this policy?
(7 point Likert scale)

OR

Imagine that the government asks that all residents voluntarily download the app to assist with contact tracing efforts. Also, your employer will now strongly encourage use of the app to enter the premises. Compliance will be encouraged by having an employee stand at the entrance of the premises to check app status. How likely are you to download the app under this policy?

(next two (ABC) have varied ordering)

[SCREEN A]

How much the app influence your choice of businesses where you shop? Would you...

- Definitely seek to switch away from a business that requires the app.
- Probably seek to switch away from a business that requires the app.
- Possibly seek to switch away from a business that requires the app.
- The app would not influence my shopping preferences
- Possibly seek to switch to a business that requires the app.
- Probably seek to switch to a business that requires the app.
- Definitely seek to switch to a business that requires the app.

[SCREEN B]

How might the app influence your choice of employment? Would you...

- Definitely seek to switch away from an employer that requires the app.
- Probably seek to switch away from an employer that requires the app.

- Possibly seek to switch away from an employer that requires the app.
- The app would not influence my employment preferences
- Possibly seek to switch to an employer that requires the app.
- Probably seek to switch to an employer that requires the app.
- Definitely seek to switch to an employer that requires the app.

[SCREEN C]

How might the app influence how you socialize? Would you...

- Definitely avoid friends and acquaintances who use the app
- Probably avoid friends and acquaintances who use the app
- Possibly avoid friends and acquaintances who use the app
- The app would not influence my socializing preference
- Possibly seek out friends and acquaintances who use the app
- Probably seek out friends and acquaintances who use the app
- Definitely seek out friends and acquaintances who use the app

(next two (AB) have varied ordering)

[SCREEN]

How much confidence do you have in **businesses** to act in the best interests of the public?

(7 point Likert scale)

[SCREEN]

How much confidence do you have in the government to act in the best interests of the public?

(7 point Likert scale)

[SCREEN]

To what extent do you agree with the following statement?

We should accept that preserving our privacy may necessitate some increase in COVID-19 related deaths.

(7 point Likert scale)

[SCREEN]

How important is privacy to you?

(7 point Likert scale)

[SCREEN]

To what extent do you agree or disagree with the following statement?

The pace of technology is too fast

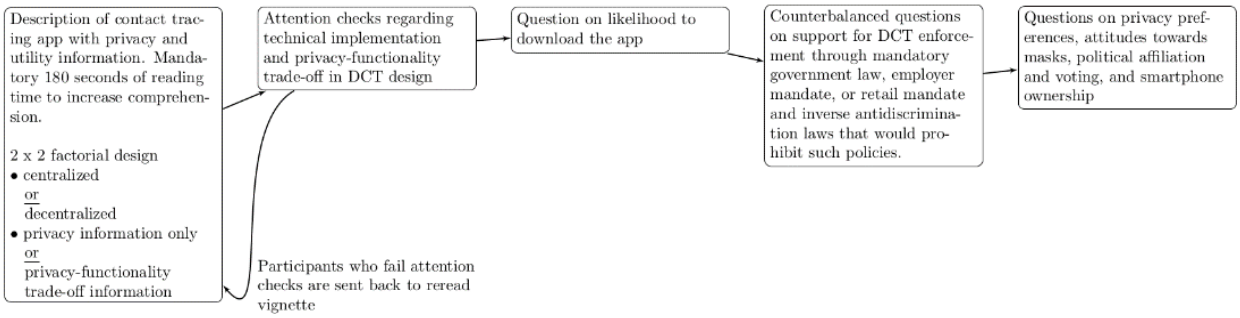
(7 point Likert scale)

[SCREEN]

Who did you vote for in the 2020 Presidential election?

- 3rd party candidate
- I didn't vote
- Biden
- Trump

10. Full text of Experiment 2



[Screen 1]

Consent block

[Screen 2]

Instructions

> You will be asked to read some information and then answer questions related to your reaction to that information. We will ask you some simple factual questions related to what you read, and if you do not answer these correctly we will require you to reread the scenario.
>
> We will also impose a minimum time per screen to read the information, and you will not be able to move forward until that time has passed.

[Screen 3]

The government is looking for ways to minimize the spread of COVID-19. In order to do so and to ease lockdowns, it announced the launch of a new app that will enable widespread contact tracing.

Contact tracing is the process of notifying all recent contacts of a person who tested positive for the virus. These recent contacts can then self-isolate and possibly get tested for the virus.

So far, contact tracing has mainly been done by public health workers. The new app will use technology to make this process more efficient and allow nationwide tracing.

The app records people's in-person encounters. If someone tests positive for COVID-19, the app indicates which other app users might also have been infected.

As a user, the app would constantly show you whether your exposure status is green, orange, or red. Green indicates that you were almost certainly not in contact with an infected person. Red means that there is a high likelihood you have been infected. Orange means that there is some lower likelihood you are infected.

The app relies on your phone's Bluetooth connection and calculates likelihood of infection based on the proximity and duration of an encounter with an infected person. For this to work, both the infected person and the potential contact must have the app on their phones. Developers believe that the app will work well in predicting infections provided that about 60% of the population downloads it.

[Screen 4]

There is an ongoing debate among researchers and health officials about whether contact tracing apps should follow a centralized or decentralized system.

(*order of text in two brackets is randomized within each treatment)*

[A centralized contact tracing system means that a single server stores all tracing data. Any information-sharing among phones in a centralized system goes through this central server.] [A decentralized contact tracing system means that information about your contacts is only stored locally on your phone. In other words, you have full control over your information.]

Decentralized contact tracing apps are considered more protective of users' privacy than centralized contact tracing apps. A centralized system offers more potential for governmental misuse of the collected data: Governments would have access to considerable troves of data about people's contacts, including who the user met at any time, where, and for how long. This

data could potentially be used for purposes unrelated to COVID-19, such as surveillance and law enforcement.

[However, the centralized system also has its advantages. Centralized systems will better assist public health authorities to forecast and respond to emerging outbreaks by creating "heat maps" that show infection patterns on a neighborhood level. Also, centralized systems record contact information for each user. This allows public health officials to directly reach out to users with a high risk of infection and offer them advice and counseling. In addition, centralized systems may enable public health officials to take measures to ensure that users observe instructions, including orders to self-isolate.]

[Screen 5]

What is a [centralized/decentralized] system? *(question is randomized)*

- A system in which a single coordinating server stores the anonymized tracing data
- A system in which no single server stores the anonymized tracing data

(ordering of two potential responses is randomized)

[Screen 6]

Which app gives the government more surveillance data on app users?

- The centralized app

- The decentralized app *(order of two potential responses is randomized)*

[Screen 7]

Given an app uptake of 60% of the population, which app will better assist health officials in tracing the contacts of an infected user?

- The centralized app
- The decentralized app *(order of two potential responses is randomized)*

Correctness enforcement: participants are automatically navigated back to the beginning of the vignette if they do not answer all three correctness checks correctly (screens 5, 6, and 7).

[Screen 8]

The government announced that the app would be launched soon using, a decentralized system

[Screen 9]

Assume that download of the app is voluntary. How likely are you to download the app after its launch?

Extremely unlikely --- Extremely likely (7 point likert scale)

[Screen 10]

Businesses could require customers to display their app status (green, orange, red) before entering their premises in order to protect other customers and employees.

How likely would you be to approve of such policies?

Extremely unlikely --- Extremely likely (7 point likert scale)

Some activists and politicians have proposed a law that **would ban companies from requiring customers to download and show their app status**. Proponents of the law say that such a practice could harm customers' privacy.

How likely would you be to support such a law?

Extremely unlikely --- Extremely likely (7 point likert scale)

[Screen 11]

Employers could require that employees display their app status (green, orange, red) before entering their premises in order to protect other employees.

How likely would you be to approve such policies?

Extremely unlikely --- Extremely likely (7 point likert scale)

Some activists and politicians have proposed a law that would ban companies from requiring employees to download and show their app status. Proponents of the law say that such a practice could harm employees' privacy and threaten their job security.

How likely would you be to support such a law?

Extremely unlikely --- Extremely likely (7 point likert scale)

[Screen 12]

Some experts have called on the government to consider **making the download of the app mandatory and requiring people to carry their phones at all times**.

How likely would you be to support such a law?

Extremely unlikely --- Extremely likely (7 point likert scale)

[Screens 10, 11, 12]

Order of questions

- Ordering of public law vs. private law questions is randomized
- Ordering of two private law questions is randomized but they are consecutive (so mandatory law does not come between private law questions)

[Screen 14]

In general, how important is privacy to you?

Not at all important --- Extremely important (7 point likert scale)

[Screen 15]

How likely would you be to support a rule requiring face masks throughout the United States to stop the spread of COVID-19?

Extremely unlikely --- Extremely likely (7 point likert scale)

[Screen 16]

Now we'd like to ask you some questions about your concerns, behaviors, and political views.

Please select all the news networks below that you view regularly (either on TV or the Internet).[4]

- Fox News
- MSNBC
- CNN
- I don't view any of these networks regularly

[Screen 17]

Which political party do you associate with?

- Democratic
- Republican
- Third-party or Incumbent

[4] In all cases of political categorical responses, ordering of responses was randomized.

[Screen 18]

Who do you expect to vote for in the 2020 Presidential Election?

- Trump
- Biden
- 3rd party candidate
- I don’t expect to vote

[Screen 19]

Do you currently own a smartphone?

- Yes
- No