Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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Full length article

Privacy concerns can explain unwillingness to download and use contact tracing apps when COVID-19 concerns are high

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ABSTRACT

Governments around the world have increasingly relied on technology to promote public health, such as using electronic health records and portable fitness devices. During the COVID-19 pandemic, "contact tracing apps" for smartphones have also been promoted in many countries as a way to allow public officials to facilitate contact tracing. But uptake in virtually all countries where such apps have been promoted is slow, one reason being privacy concerns. Conducting three experiments across France (n = 471), Australia (n = 202), and the United States (n = 1005), we explore if salient COVID-19 concerns, which intuitively should increase concerns about personal and public health, might in fact increase privacy concerns and thereby reduce uptake of contact tracing apps. Using an experimental design where we randomly assign participants to either a disease concerns or control condition, we find that salient COVID-19 concerns decrease intentions to download contact tracing apps. Mediation results reveal that greater valuations of privacy explain the lower willingness. We therefore explain why COVID-19 contact tracing apps that are promoted when the pandemic is at its peak see low levels of uptake. Our results provide policy makers with implications concerning how to promote uptake to help "flatten the curve" of not just the current pandemic but potentially also future ones.

As of December 2020, there were over 81 million infections of COVID-19 and over 1.8 million deaths around the world. Luckily, over 57 million have also recovered from the deadly disease. The pandemic resulted in a seismic shift in how people live, work, and play, with the worldwide economy being shattered, families unable to see loved ones, and air travel coming to a halt (Garfin, Silver, & Holman, 2020). Given the severity of the COVID-19 disease, doctors, policy makers, and government officials have introduced measures to help "flatten the curve" such as by introducing guidelines—sometimes mandates—concerning staying-at-home, wearing face masks, and social distancing when outside (Anderson, Heesterbeek, Klinkenberg, & Hollingsworth, 2020; Chan, 2020a, 2020b; Feng et al., 2020; Glass, Glass, Beyeler, & Min, 2006; Horwell & McDonald, 2020; Jia et al., 2020; Lewnard & Lo, 2020; Wu et al., 2020).

One particular effective method to help "flatten the curve" is to conduct contact tracing. Contact tracing has long been recognized to help keep pandemics at bay (Ahmed et al., 2020; Eames & Keeling, 2003; Klinkenberg, Fraser, & Heesterbeek, 2006; Kretzchmar et al., 2020). When a person is known to have been infected with a disease, such as COVID-19, public health officials usually "race against time" to find all known contacts of the person in their recent days, contacting those persons and asking them to quarantine in order to avoid subsequent spread of the disease. In efforts to conduct contact tracing during the COVID-19 pandemic, some Asian countries such as the People's Republic of China and Republic of Korea have accessed people's banking and mobile records to determine where an infected person has been (COVID-19 National Emergency Response Center, 2020; Sternlicht, 2020).

Another tool that countries have used to facilitate contact tracing is via the introduction and promotion of "contact tracing" apps for people to download on smartphones (Ahmed et al., 2020; Kretzchmar et al., 2020). Relying on Bluetooth technology, these apps "detect" if the smartphone user is near someone else with the same app for a specified amount of time (usually 15 min). This digital interaction is then recorded, allowing public health officials to quickly contact the other individual via a notification on their app if they are deemed at-risk from possible exposure to an infected individual. Many countries including South Korea along with others such as Singapore and Australia have already introduced such apps, while other countries such as the United Kingdom and France have either discussed it or planning on introducing

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contact tracing apps. For a list of countries as of December 2020, please see Appendix 1. Contact tracing apps have been promoted, moreover, not just with the goal to conduct contact tracing. In Australia, Prime Minister Scott Morrison encouraged Australians to download the CovidSafe app on phones in exchange for reducing lockdown measures back in May 2020.

But, uptake of tracing apps is slow. The app in Australia was introduced in May 2020. As of December 2020, only 7.1 million downloads have been recorded (Barbaschow, 2020), far short of the 40% of the 26 million population in the nation that Prime Minister Scott Morrison said was required for the app to be effective (Dick, 2020). Low uptake levels in Singapore promoted the Prime Minister Lee Hsien Loong in the South-East Asian city-state to legally enforce its download back in October 2020 (Nakano, 2020). There are also low levels of uptake in other countries where the apps have been introduced, such as India, Norway, and Singapore, thereby hampering efforts in tracing contacts and flattening the curve (Findlay, Palma, & Milne, 2020). The question is interesting then. One would intuitively envisage that concerns about one's own and the public's health would be greater when a viral disease is rampant. Why is there low uptake of contact tracing apps when the goal of these apps is to promote both personal and public health, especially in the face of a deadly viral pandemic?

1. Hypothetical development

One of the key reasons for the resistance against the use, download, and adoption of any contact tracing app is due to the potential invasion of personal privacy (Findlay et al., 2020; Meade, 2020; Rudgard, 2020), which consumers must weigh against the potential benefits for public and also their personal health as with many other technological advances such as electronic health records (Jozani, Ayaburi, Ko, & Choo, 2020; Park & Shin, 2020). Indeed, contact tracing apps often require giving away one's movements and possibly (depending on the app or country) medical information, increasing reluctance among the public to download and use these apps. For example, in India, which introduced the "Aarogya Setu" app in April 2020 (with only 127.6 million downloads by July), had few privacy safeguards, with data collected being stored in centralized servers but without any data protection laws in place (Arun, 2020). In Australia, concerns about its CovidSafe app largely surrounded the fact that there are now legal restrictions about secondary use of any data collected with the app beyond its primary purpose of protecting public health (Remeikis, 2020). Could privacy concerns trump even concerns about health, during a time when health intuitively should be weighted more on people's minds?

There are theoretical reasons to posit that promoting contact tracing apps when concerns about COVID-19 are high may counter-intuitively reduce uptake. This is a thesis that we offer and test in this research. The extant literature proffers that disease concerns trigger a so-called "behavioral immune system" that results in behaviors and choices that help oneself prevent infection (Ackerman, Hill, & Murray, 2018; Schaller & Park, 2011). This system acts along with the physiological immune system by making people aware of even *cues* of disease, thereby protecting them from infectious risks, before the physiological immune system is even engaged. For example, when disease concerns are salient, people are attracted to members of the opposite sex with symmetrical faces that signal health (Gangestad & Buss, 1993) and they are averse to members of the out-group because, in evolutionary times, out-group members carried diseases to which one was not immune, which has persisted until today (Terrizzi, Shook, & McDaniel, 2013). Seemingly irrational but the actions psychologically allow one to immunologically protect oneself as a first line of defence.

Another outcome of the behavioral immune system is social conservatism (Ackerman et al., 2018). That is, when disease concerns are salient, people tend to become more conservative socially, within their daily social interactions and activities. For example, when disease concerns are salient, people conform to social and other group norms (Murray & Schaller, 2012) and are averse to violations of moral standards (Horberg, Oveis, Keltner, & Cohen, 2009), all of which are consistent with being conservative. This is because conservative social norms and habits such as reducing contact with unknown others and avoiding "disgusting" things may help lower infection risks.

Social conservatism is defined as "any sociocultural value system that encourages strict adherence to social norms and emphasizes social exclusivity" (Terrizzi et al., 2013). Adherence to social norms helps to ensure that in-group members do not behave in ways that are contrary to the group's best interest and helps to distinguish in-group members from outgroup members (Triandis, 1994). Right-Wing Authoritarianism and Social Dominance Orientations are also examples of socially-conservative value systems. However, value systems, including socially-conservative ones, also include other preferences and traditions. This means, for our current inquiry, that disease concerns might elicit other preferences and traditions associated with social conservatism, and not just those related to protecting oneself from disease risks. Indeed, studies from social and cognitive psychology have shown that when a concept is activated, it can trigger a host of behaviors and judgments consistent with that concept (Wheeler, DeMarree, & Petty, 2007).

One key aspect of social conservatism related to our inquiry is the emphasis on minimal governmental oversight and intrusion into people's daily lives. That is, social conservatism includes a preference for "small government" including a greater stress on personal privacy in that conservative values generally oppose governmental oversight into one's personal lives (Jost, Federico, & Napier, 2009; Margulis, 1977; Milne & Rohm, 2000; Viguerie, 2013; Wartenberg & Thompson, 2010; Westin, 2003). There are times when social conservatism is accepting of intrusion, such as when it protects the interests of law and order (Pew, 2016), which social conservatism also values, but a socially-conservative value system usually places a higher value on personal privacy. Thus, in the present context, when disease concerns are acute and salient, this might increase social conservatism—including greater privacy concerns. This could potentially explain why, when contact tracing apps are introduced *after* the COVID-19 pandemic when disease concerns are already high, worries about privacy deter people from downloading and using these apps.

Indeed, worries about personal privacy intrusions have been a key barrier facing adoption of new technologies. This includes so-called "m-health" or mobile health technologies that use mobile applications, wearable devices, and health record systems, such as those to help diabetics manage their sugar and food intake (Conger, Pratt, & Loch, 2013; Eng & Lee, 2013; Fox & Connolly, 2017). A focus on privacy as a barrier to technology adoption goes beyond the use of traditional models of technology adoption such as the Technology Adoption Model (Davis, Bagozzi, & Warshaw, 1989) or Unified Theory of Technology Acceptance and Use (Venkatesh, Morris, Davis, & Davis, 2003). These models offer insights into technology adoption based on key factors such as social influence and effort expectancy. However, there are two limitations to these models. First, there has been mixed support for the constructs of social influence and effort expectancy in technology adoption (Or et al., 2011). Second, more importantly for us, these models do not capture all factors relevant to *health* technology adoption, which includes the role of privacy on m-health adoption (Wu, Wang, & Lin, 2007). Thus, we move beyond a reliance on technology adoption to explore the role of greater conservatism and privacy concerns when disease concerns, including those about COVID-19, are salient in the willingness to download and use contact tracing apps.

2. The current research

Formally, we predict that salient disease concerns will actually reduce uptake of contact tracing apps because of a greater weight placed on protecting one's personal privacy over protecting one's health. This is counter-intuitive as, when disease concerns are high, protecting one's

(and the public's) health should be primary, but based on the behavioral immune system, we suggest that greater social conservatism and valuation of personal privacy may be greater than both personal and public health concerns. Please see Fig. 1 for a graphical illustration of our conceptual framework and Table 1 for an overview of the experiments.

We test our hypothesis in the COVID-19 context in three experiments. We employ an experimental methodology to allow us to determine causation, answering a call for such an approach in understanding how people use and respond to information technology (Chan & Saqib, 2015; Tourangeau, Couper, & Steiger, 2003). In Experiment 1, we test our hypothesized effect of salient COVID-19 concerns on willingness to download contact tracing apps in the French context. Experiment 2 replicates this in the Australian context while also showing that COVID-19 concerns increase social conservatism as an investigation into the likely mechanism. Finally, Experiment 3 once again replicates the key effect in the American context while specifically testing the privacy concerns that are salient when COVID-19 concerns are high, and how privacy concerns reduce willingness to download contact tracing apps.

3. Experiment 1

In April 2020, France (along with many European countries) was considering contact tracing apps as a response to the COVID-19 pandemic (Onishi & Méheut, 2020). Drawing on this real-life (and real-time) consideration of contact tracing apps, we recruited French participants for Experiment 1, with the purpose of testing of salient COVID-19 concerns would actually reduce willingness to download and use such apps. We used a one-factor, three-level experimental design with participants randomly assigned to a condition where COVID-19 was made salient or to one of two control groups where it was not. Our hypothesis was that participants in the treatment group would be less willing to adopt contact tracing apps relative to the control groups.

3.1. Procedure

We recruited 471 French citizens from a professional online panel (M_{age} = 38.93 years old, *S.D.* = 12.92 years old; 222 men, 146 women, 3 non-disclosed). They all received monetary compensation in return for 15 min of their time. A sensitivity analysis conducted using G*Power revealed that our sample size could test an estimated effect size of f = 0.14 at the alpha = .05 and power = .80 levels (Faul, Erdfelder, Buchner, & Lang, 2009). Experiment 1 was conducted in French. Please refer to the Supplementary Materials for the original stimuli in French, translated into English in the write-up.

We randomly assigned participants to either the disease concerns or one of two control conditions. We made salient COVID-19 concerns by asking our participants to think of the most recent news they read about COVID-19, and to briefly describe what the news was about. We included two control conditions. In the first, we asked our participants to think of the most recent news articles *not* about COVID-19, as we wanted participants to also think of news articles to maintain an equivalence on this dimension to the treatment group. But since we explicitly asked people to *not* consider COVID-19 news in this condition, we could have still made COVID-19 concerns salient. Therefore, in a second control group, we asked participants to describe the most recent movie that they watched. Disease concerns should not be salient here.

We then presented participants with information about the contact tracing app called "StopCovid" that the government was considering. (As of October 22, 2020, the app was renamed "TousAntiCovid," or "EveryoneAgainstCovid.") Participants were given details about the app, what it would entail, and the main purposes of the app. We asked them how likely, willing, and how interested they were in using such an app on their phones, on separate 7-point scales (1 = Not at All, 7 = Very Likely/Willing/Interested).

We then asked how much participants were thinking of COVID-19 during the study on a 7-point scale (1 = Not at All, 7 = Very Much), which served as our manipulation check. We also asked participants how much they supported the French government's efforts in combating the COVID-19 pandemic, also on a 7-point scale (1 = Not at All, 7 = Very Much). We used this as a co-variate.

Lastly, in our demographic questions, we asked if participants owned a smartphone. All indicated that they owned a smartphone, perhaps unsurprisingly, so we included all participants' responses in our data analysis.

3.2. Results

3.2.1. Analysis approach

We used one-way ANOVAs to test for possible differences on our disease concerns manipulation check, intentions to download StopCovid (α = 0.93), and support for governmental efforts against COVID-19 between the three conditions (experimental and two controls). The distribution for each of the dependent variables failed normality assumptions (Shapiro-Wilk statistic for manipulation check = .83, p < .001; for intentions = 0.95, p < .001; lastly, for support = .91, p < .001), and so we used separate ANOVAs instead of a MANOVA to analyze our data.

3.2.2. Manipulation check

A one-way ANOVA revealed a significant difference across the three conditions, F (2, 468) = 8.25, p < .001, d = 0.26 (95% CI: 0.08, 0.44). Those asked to think of COVID-19 news scored higher (M = 5.85, *S.D.* = 1.38) than both those asked to think of non-COVID-19 news (M = 5.20, *S.D.* = 1.75; t [388] = 4.03, p < .001, d = 0.40 [95% CI: 0.20, 0.61]) and also those thinking of a recent film (M = 5.41, *S.D.* = 1.62; t [277] = 2.28, p = .015, d = 0.27 [95% CI: 0.03, 0.51]). Importantly, scores in the two control conditions did not differ (t [271] = 0.89, p = .37), suggesting that disease concerns were similarly less salient in both these conditions relative to the treatment or experimental group. The results are robust taking into consideration of Bonferroni adjustments (with 3 comparisons, resulting in a corrected alpha of p = .017).

3.2.3. Intentions to download StopCovid

We averaged the three items (α = 0.93) to form a single index of intentions to download the contact tracing app. A one-way ANOVA revealed a significant difference across the three conditions, F (2, 468) = 20.61, p < .001, d = 0.41 (95% CI: 0.23, 0.60). Participants asked to think of COVID-19 news scored lower (M = 4.76, *S.D.* = 1.24) than both those asked to think of non-Covid news (M = 5.52, *S.D.* = 1.15; t [388] = 6.28, p < .001, d = 0.64 [95% CI: 0.43, 0.84]) and also those thinking of a recent movie (M = 5.36, *S.D.* = 1.26; t [277] = 3.68, p < .001, d = 0.44 [95% CI: 0.20, 0.68]). Scores in the two control conditions did not differ (t [271] = 0.99, p = .32). Salient COVID-19 concerns, consequently, decreased intentions to download and use the contact tracing app compared to the two controls. The results are robust taking into consideration of Bonferroni adjustments (with 3 comparisons, resulting in a corrected alpha of p = .01). See Fig. 2.

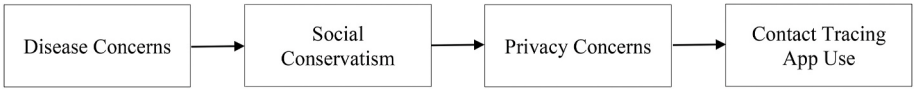

Fig. 1. Theoretical model.

Table 1
Overview of experiments.

Experiment	Objective	Sample	Mediators Measured	Dependent Outcome	Findings
1	To test effect of salient disease concerns on contact tracing app use.	471 French	None	Intentions to download StopCovid (binary)	Salient COVID-19 concerns reduced intentions to download StopCovd.
2	To test indirect effect of salient disease concerns on contact tracing app use via greater social conservatism.	202 Australians	Social conservatism	Choice to download CovidSafe (binary)	Salient COVID-19 concerns decreased choice to download CovidSafe due to greater social conservatism.
3	To test indirect effect of salient disease concerns on contact tracing app use via greater privacy concerns.	1005 Americans	Personal privacy concerns	Willingness to download app (Likert)	Salient COVID-19 concerns decreased willingness to download app due to greater personal privacy concerns.

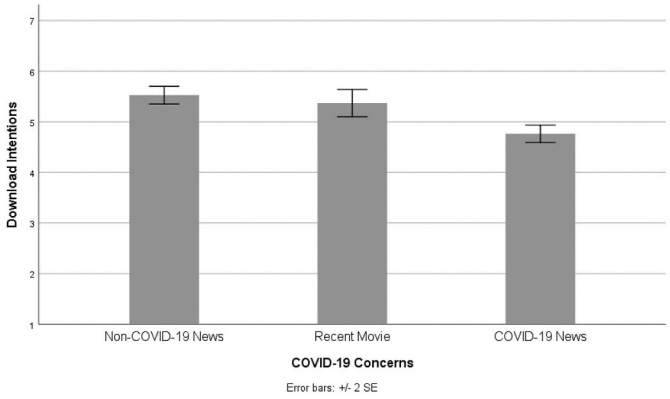

Fig. 2. Experiment 1: Download intentions depending on COVID-19 concerns.

3.2.4. Support for French government efforts

A one-way ANOVA revealed no significant difference in COVID-19 concerns across the three conditions, F (2, 468) = 1.88, p = .15. Participants who were asked to think of COVID-19 scored similarly (M = 4.74, *S.D.* = 1.70) as those asked not to think of COVID-19 news (M = 4.67, *S.D.* = 1.82) and also participants who were asked to think of a recent film (M = 5.11, *S.D.* = 1.82). As there were no differences across the conditions on this variable, we did not conduct any further analyses on it.

3.3. Discussion

The results provide initial evidence that salient COVID-19 concerns reduce consumers' willingness to use a contact tracing app to help flatten the curve. This goes against intuition, that when such concerns are salient, efforts should be made to protect oneself from disease, which would presumably include downloading and adopting such apps. However, our argument is that salient disease concerns, including those about COVID-19, elicit greater social conservatism, presumably including greater emphasis on personal privacy, thereby trumping privacy concerns. This experiment did not assess these presumed explanations. Thus, we turn to Experiment 2 to examine the likely role of greater social conservatism in the effect; then in Experiment 3, we turn to examining the specific role of personal privacy valuations.

4. Experiment 2

In Experiment 2, we sought to replicate the key effect with a few changes. Firstly, we recruited an Australian sample to generalize the effect. In April 2020, Australia was also considering the use of a contact tracing app known as "CovidSafe" over which many Australians expressed privacy concerns (Meade, 2020). In fact, even Members of the Australian Parliament expressed such concerns themselves (Hunter & Koziol, 2020). This made it apt and timely for us to replicate the results in the Australian context. Secondly, we used a choice measure in this experiment instead of self-reported intentions in Experiment 1. Thirdly, and importantly, we tested the role of greater social conservatism, which prior research suggest might arise because of disease concerns (Gangestad & Buss, 1993; Terrizzi et al., 2013). Thus, we measured conservatism and expected that it will explain the effect of salient COVID-19 concerns on choice to use CovidSafe in Australia.

4.1. Procedure

We recruited 202 Australian citizens who were also undergraduates (M_{age} = 19.99 years old, *S.D.* = 2.32 years old; 86 men, 116 women). They received course credit in return for 15 min of their time. A sensitivity analysis conducted using G*Power revealed that our sample size could test an estimated effect size of d = 0.35 at the alpha = .05 and power = .80 levels (Faul et al., 2009). Here, we had focused on students because, in Australia and many other nations, young adults are a leading cause of infection spread, and so, when the CovidSafe app was launched in Australia, primary segments of the population targeted included young adults (Norman, 2020). Moreover, in Australia, citizens are required to vote and so even students at the undergraduate level should have some inkling about their political views, which is important as we measured social conservatism in this experiment, which was conducted in English. Please see the Supplementary Materials for the exact stimuli. Importantly, we conducted this study when the CovidSafe app was *about* to be introduced, and so there was no one who had already used the app at the time of the study.

We randomly assigned our participants to either the disease concerns condition, as in Experiment 1, or the condition in which they were asked to think of a news article unrelated to COVID-19. Given the small sample we were able to recruit, and the fact that the two control conditions in Experiment 1 did not differ, we did not include a second control condition in this experiment (the condition about a recent movie seen).

After this, participants were given a short description of the CovidSafe contact tracing app proposed by the Australian federal government, and we asked them if they would download and install CovidSafe, providing us with a binary yes/no response.

To measure social conservatism, we asked participants to indicate their agreement with the following items: "Society needs to place more emphasis on traditions and values; " "The evolution of society is moving so quickly that we are losing our history, traditions, and values; " and "Homosexuality should be discouraged," all on 9-point scales (1 = Strongly Disagree, 9 = Strongly Agree). The statements were adapted from the Pew Research Center's Ideological Consistency Scale (ICS; Pew Research Center, 2014). This is a scale used commonly in public opinion polling (vs. academic research), with three notable adaptations. First, the ICS includes 10 pairs of statements that present both a liberal and a conservative viewpoint on different issues (e.g., homosexuality, big business). But, as some pairs were about economic conservatism, we only focused on those that pertained to social conservatism. Second, in order for us to devise a continuous measure, we only presented the conservative viewpoint instead of having our research participants choose between a liberal and a conservative one, and asked students to indicate their agreement with each item on a Likert-type response.

Third, the ICS was originally designed in the American context, and so we excluded items (e.g., those about African Americans) that were not relevant to the Australian context. This resulted in a final adapted ICS with three items.

Finally, we included the same manipulation check of disease concerns as Experiment 1, except this time we used a 9-point scale (1 = Not at All, 9 = Very Much). Also, we asked students the same control question about support for the Australian federal government's efforts in combating COVID-19, also on a 9-point scale (1 = Not at All, 9 = Very Much).

4.2. Results

4.2.1. Analysis approach

We used independent samples *t*-tests or logistic binary regression analysis to test for possible differences on our disease concerns manipulation check, whether or not to use CovidSafe, conservatism, and support for governmental efforts between the experimental and control conditions.

4.2.2. Manipulation check

An independent samples *t*-test revealed that salient COVID-19 concerns did increase participants' thinking about the disease during the experiment ($M = 5.98$, $S.D. = 1.15$) more so than in the control condition ($M = 4.96$, $S.D. = 1.85$), $t\,(200) = 4.82$, $p < .001$, $d = 0.68$ (95% CI: 0.39, 0.96).

4.2.3. Choice to download CovidSafe

A Chi-square analysis revealed that, among students in the salient COVID-19 concerns condition, only 56.2% were willing to download the app, compared to 73.6% in the control, $\chi^2\,(1) = 6.01$, $p = .01$, Wald = 12.11, Exp(B) = 1.65. See Fig. 3.

4.2.4. Social conservatism

We averaged the three items of conservatism ($\alpha = 0.89$) to form a single index. An independent samples *t*-test revealed that the salient COVID-19 concerns condition scored higher on conservatism ($M = 4.74$, $S.D. = 1.48$) in comparison to the control condition ($M = 3.78$, $S.D. = 1.28$), $t\,(200) = 4.60$, $p < .001$, $d = 0.65$ (95% CI: 0.36, 0.93). See Fig. 4.

4.2.5. Mediation analysis

We conducted a mediation analysis using Model 4 of the Preacher and Hayes (2008) bootstrapping protocols to see if conservatism could explain why disease concerns would decrease the choice to download the tracing app. If the confidence interval for the indirect effect of the independent variable X (disease concerns) on the dependent variable Y (choice to download app) through the presumed mediating variable M (conservatism) does not include 0, mediation is said to occur, in that $X \rightarrow M \rightarrow Y$. Bootstrapping is a stronger test than the Baron and Kenny (1986) and Sobel tests (1982) in two ways. First, Baron and Kenny argued that there must be a significant zero-order effect of X on Y. Without it, there is no reason to further examine whether or not M mediates the effect. Recent research has criticized the requirement of a direct effect for a mediation analysis that is meaningful (Preacher & Hayes, 2004; Zhao, Lynch, & Chen, 2010). Second, according to Preacher and Hayes (2004, 2008), the Sobel test improperly relies on normal distribution theory, but however, the indirect effect in its analysis is the product of two parameters, which means that the sampling distribution of products is not necessarily normal. Bootstrapping corrects the issue by using the sample data to estimate the sampling distribution of the indirect effect by re-sampling the data.

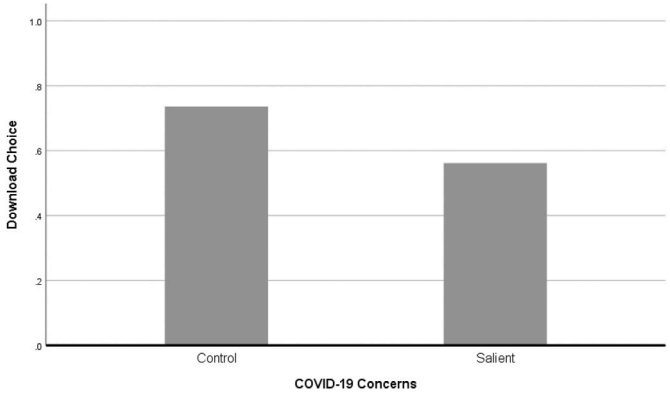

Fig. 3. Experiment 2: Download choice depending on COVID-19 concerns.

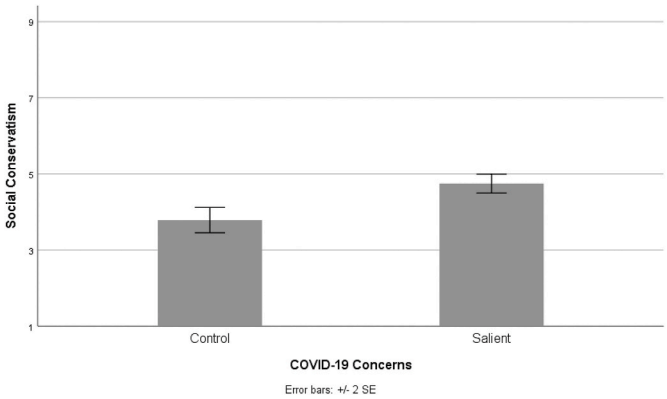

Fig. 4. Experiment 2: Social conservatism depending on COVID-19 concerns.

The indirect effect of salient COVID-19 concerns on choice to download the app via social conservatism was estimated to lie at −0.09 (*S.E.* = 0.03; 95% CI: 0.16, −0.04; 5000 bootstrapped samples). Thus, our proposed process was supported. COVID-19 disease concerns boosted social conservatism, decreasing willingness to use CovidSafe. See Fig. 5.

4.2.6. Support for Australian Government efforts

An independent samples *t*-test revealed that participants in the salient COVID-19 concerns condition scored similarly ($M = 5.23$, $S.D. = 1.41$) as those in the control ($M = 5.31$, $S.D. = 1.44$), $t\,(200) = 0.35$, $p = .72$. As there were no differences across the conditions on this variable, we did not conduct any further analyses on it.

4.3. Discussion

Encouragingly, these findings within a different national context—namely, Australia—still replicate those from Experiment 1 within the French context. Here, we see again that COVID-19 disease concerns, when salient, decrease willingness to use the CovidSafe contact tracing app among Australian undergraduates—one of the key target markets for CovidSafe when it was first developed and designed. We use the same treatment and control conditions as earlier. Importantly, we find that greater conservatism can explain why salient COVID-19 concerns reduce consumers' intention of downloading and using the tracing app proposed by the Australian government. Specifically, greater disease concerns increase support of socially-conservative viewpoints that, then, explained their lower willingness to download, use, and adopt CovidSafe.

However, this experiment, although encouraging, still has its limitations. One concern is that this Australian context, and previously in France, are ones in which talk about a contact tracing app was already acute, so participants already may have developed some initial attitudes toward it quite likely. It is unclear, if our effect would arise in a context where there is little (if not *no*) talk of such an app. The other concern is that we illustrate the mediating effect of social conservatism, but not of greater emphases on personal privacy in particular. Thus, we turn to

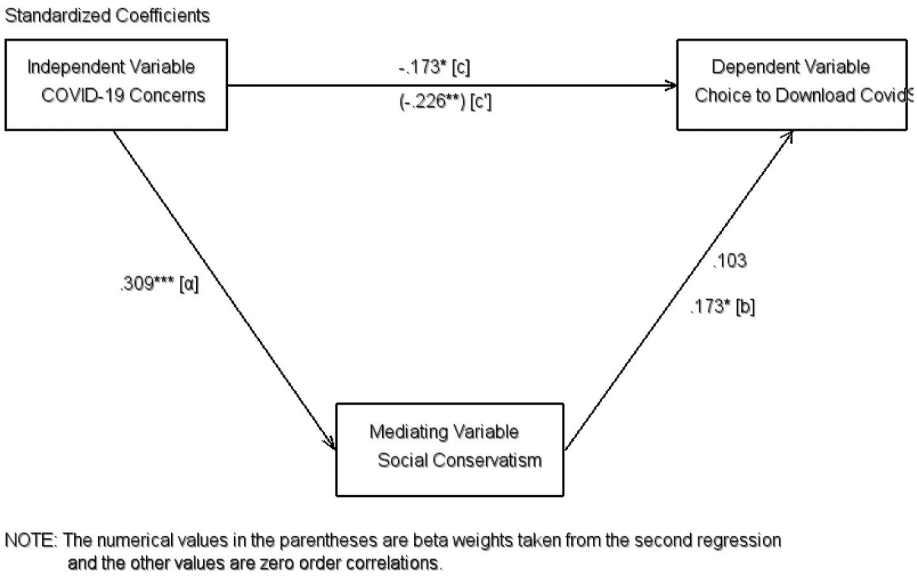

Fig. 5. Experiment 2: Individual pathways in mediation analysis.

Experiment 3 in which we assess our effect in the American context and, especially, the potential mediating role of personal privacy valuations.

5. Experiment 3

The main focus of Experiment 3 was to explore the specific role of greater concerns or valuations regarding personal privacy in explaining why salient disease concerns decrease willingness to use contact tracing apps. We also examined, once again, the role of conservatism, but this time using a moderation-based approach. Specifically, we coded the state of each U.S. participant as either "Democratic" or "Republican" (see method below). Our expectation was that salient disease concerns would increase personal privacy valuations and decrease one's willingness to use contact tracing apps *primarily for participants living in Democratic states*. While not an exact substitute, how Democratic or Republican each state is generally serves as a proxy for each state citizens' political ideology. Indeed, the majority of Californians and Illinoisans are Democratic, and the states have Democratic governors and often vote Democratic in the Presidential elections; likewise, the majority of Texans are Republican, and the state has a Republican governor and tend to vote Republican in the Presidential election. Thus, our logic was as follows: If the effects of salient COVID-19 concerns on both privacy and the willingness to use contact tracing apps arise because of greater social conservatism (which Experiment 2 finds, but mediation-based effects are limited in their conclusions), then the effects should arise primarily in Democratic states or among Democratic participants. For Republican states or among Republicans, because they are already largely conservative, if salient disease concerns do elicit greater social conservatism, any effect should be marginal.

Assessing state-level data is furthermore beneficial for practice as it is a geographic basis for segmenting areas of the country, with consequences for policy makers in understanding where to promote tracing apps, and when. We elaborate on some practical benefits later on in our General Discussion.

5.1. Procedure

We recruited 1005 American citizens from Amazon's Mechanical Turk (M_{age} = 36.83 years old, *S.D.* = 12.57 years old; 555 men, 445 women, 5 non-disclosed). We used TurkPrime to manage the recruitment process (Litman, Robinson, & Abberbock, 2017), which automatically pays participants (instead of having us manually do so) when they provide the correct "password" that confirms that they completed the study in full. The use of MTurk is popular in social sciences as it is a low-cost platform and quick to recruit large sample sizes in a short amount of time (Paolacci & Chandler, 2014; Rouse, 2015). Samples from MTurk are also representative of Democrats and Republicans in the general population (Clifford, Jewell, & Waggoner, 2015), and thus MTurk samples serve as a useful (and valid) participant recruitment tool for political research. A sensitivity analysis conducted using G*Power revealed that our sample size could test an estimated effect size of f = 0.08 at the alpha = .05 and power = .80 levels (Faul et al., 2009). All participants received monetary compensation for 15 min of their time. The experiment was in English. Please refer to the Supplementary Materials for the exact stimuli.

We firstly manipulated salient COVID-19 concerns by presenting participants 10 news headlines, without stating the source, about the disease. In the control condition, we presented participants 10 news headlines not about the disease. Ostensibly, we were conducting market research for an unspecified news agency about "How news headlines should be written." Please see the Supplementary Materials for the headlines. In both conditions, for each news headline, participants indicated how "succinct" they found each headline, under a guise of market research for the non-disclosed news agency.

One advantage of an American sample is that, as of April 2020, there were no contact tracing apps proposed by the state or federal governments in the U.S. This allowed us to assess participants' willingness to download such an app *if proposed* by the government, while in the prior French and Australian contexts the federal governments had already discussed such an app and participants were already familiar with it, leading to possible *a priori* knowledge or preference concerns. Hence, we presented all our American participants here with a news article stating that the government was proposing a contact tracing app to be implemented starting in May one month later. All participants indicated, on a 7-point scale, their willingness to download and use the tracing app (1 = Not at All, 7 = Very Willing).

We then asked participants to indicate how much they valued their personal privacy on a 7-point scale; this was our potential mediating measure. Specifically, we asked them to do so in relation to concerns about public health (1 = Greater Emphasis on Personal Privacy, 7 = Greater Emphasis on Public Health), thus we had participants trade-off the pros and cons of the apps as serving public health but at the potential cost of privacy. We also asked them "How much do you trust your state government?" on a 7-point scale (1 = Not at All, 7 = Very Much); this

was to test a potential trust rival account. Perhaps it was not greater conservatism or privacy concerns *per se*, but disease concerns reduce trust? Then, they indicated how much they thought about COVID-19 while they were completing the study as in the two previous experiments, but here on a 7-point scale (1 = Not at All, 7 = Very Much).

During demographics, in addition to gender and age, we asked participants which state they lived in. This allowed us to determine the political ideology of each participant based on the state in which they resided (see below).

5.2. Results

5.2.1. Analysis approach

We used two-way ANOVAs to test for possible differences on our COVID-19 concerns manipulation check, intentions to download the app, valuation of personal privacy, and trust in government across four conditions (state political ideology × disease concerns). The distribution for each of these four dependent variables failed normality assumptions (Shapiro-Wilk statistic for manipulation check = .90, $p < .001$; for intentions = 0.86, $p < .001$; for personal privacy valuation = .87, $p < .001$; and for trust = 0.76, $p < .001$), so we used separate ANOVAs instead of a MANOVA to analyze our data.

5.2.2. State political ideology categorization

There are many ways to determine how "Democratic" or "Republican" each state in the U.S.A. is. Our approach is as follows. We considered whether the state voted Hillary Clinton (Democratic) or Donald Trump (Republican) in the 2016 Presidential election and also the party of each state governor as of November 2019. If there was a match, we considered the resulting match (whether Democrat or Republican) as the political ideology of the state. Where there was a difference, we considered whether there was a match in political party in the state house and state senate. Thus, for example, Kansas voted for Trump but has a Democratic governor, which was a mismatch. However, as the Kansas senate and house both were Republican, we considered the state of Kansas to be a Republican state. Please see Appendix 2.

5.2.3. Manipulation check

A 2 (Democratic, Republican state) × 2 (control, disease concerns) ANOVA revealed only a main effect of our disease concerns manipulation on concerns about COVID-19, F (1, 1001) = 179.74, $p < .001$, d = 0.84 (95% CI: 0.71, 0.97): Those who read COVID-19 headlines scored higher (M = 4.99, $S.D.$ = 1.82) than those who read control headlines (M = 3.37, $S.D.$ = 1.93). There was no main effect of political ideology, F (1, 1001) = 1.36, p = .24. There was also no two-way interaction, F (1, 1001) = 1.55, p = .21. Hence, our manipulation was successful.

5.2.4. Intentions to download contact tracing app

A 2 × 2 ANOVA indicated a main effect of state political ideology, F (1, 1001) = 5.80, $p < .001$, d = 0.15 (95% CI: 0.02, 0.27): Those in Republican states scored lower (M = 4.61, $S.D.$ = 2.03) than Democratic states (M = 4.93, $S.D.$ = 2.17). Further, there was a main effect of salient disease concerns, F (1, 1001) = 20.44, $p < .001$, d = 0.28 (95% CI: 0.16, 0.41): Those who read COVID-19 headlines scored lower (M = 4.45, $S.D.$ = 2.08) than those who read control headlines (M = 5.12, $S.D.$ = 2.00).

Importantly, there was also a two-way interaction, F (1, 1001) = 5.16, p = .02, d = 0.14 (95% CI: 0.01, 0.26). Thus, we examined the data further, by examining the impact of salient disease concerns firstly in Democratic states and then in Republican states. The effect of COVID-19 concerns, when salient, should be most pronounced in the former, if such concerns indeed make people more conservative, but attenuate in the latter, as participants are already quite conservative. Consistent with this, in Democratic states, salient disease concerns lowered app-use intentions (M = 4.46, $S.D.$ = 2.11) compared to the control (M = 5.36, $S.D.$ = 1.84), F (1, 633) = 33.37, $p < .001$, d = 0.45 (95% CI: 0.30, 0.61). But in Republican states, salient disease concerns did not affect app intentions (M = 4.44, $S.D.$ = 2.03) compared to the control (M = 4.74, SD = 2.17), F (1, 368) = 1.83, p = .17. See Fig. 6.

5.2.5. Valuation of personal privacy

A 2 × 2 ANOVA revealed a main effect of political ideology, F (1, 1001) = 9.96, p = .002, d = 0.19 (95% CI: 0.07, 0.23): Participants in Republican states scored lower (M = 4.12, SD = 2.40) than in Democratic states (M = 4.46, SD = 2.02), consistent with the general greater emphasis on privacy among Republicans. There was a main effect of salient disease concerns also, F (1, 1001) = 5.76, p = .01, d = 0.15 (95% CI: 0.12, 0.27): Participants who read COVID-19 headlines scored lower (M = 4.06, SD = 2.24) than those who read control headlines (M = 4.57, SD = 2.08), consistent with our general contention that greater disease concerns should increase privacy valuations.

Importantly, there was also a two-way interaction, F (1, 1001) = 4.08, p = .04, d = 0.12 (95% CI: 0.003, 0.25). Thus, we examined the data further. Consistent with our predictions, in Democratic states, salient disease concerns increased privacy valuations (M = 4.08, $S.D.$ = 2.10) compared to the control (M = 4.81, $S.D.$ = 2.10), F (1, 633) = 21.51, $p < .001$, d = 0.36 (95% CI: 0.21, 0.52). However, in Republican states, salient disease concerns did not affect valuation of personal privacy (M = 4.03, $S.D.$ = 2.50) compared to the control group (M = 4.19, $S.D.$ = 2.32), F (1, 368) = 0.40, p = .52. See Fig. 7.

5.2.6. Moderated mediation

Using Model 8 of the bootstrapping protocols, we explored the potential moderating effect of state political ideology and subsequent mediating effect of valuation of personal privacy in a moderated mediation model. Among Democratic states, the indirect effect of salient COVID-19 concerns on intentions to download the app was significant, estimating at −15 ($S.E.$ = 0.04; 95% CI: 0.24, −0.07). However, among Republican states, the indirect effect was insignificant, estimating at −0.03 ($S.E.$ = 0.05; 95% CI: 0.14, −0.07). Most importantly, the index of moderated mediation was significant, estimating at 0.11 ($S.E.$ = 0.06; 95% CI: 0.01, 0.25). As such, these results supported our predictions. The results indicate that salient COVID-19-concerns reduced willingness to download and use contact tracing apps due to greater privacy concerns—but this effect primarily arose for Democratic states, less so for Republican states.

5.2.7. Trust in U.S. Government

A one-way ANOVA revealed a main effect of state political ideology, F (1, 1001) = 1399.27, $p < .001$, d = 2.36 (95% CI: 2.20, 2.52): Those residing in Republican states scored higher (M = 5.92, SD = 1.13) than

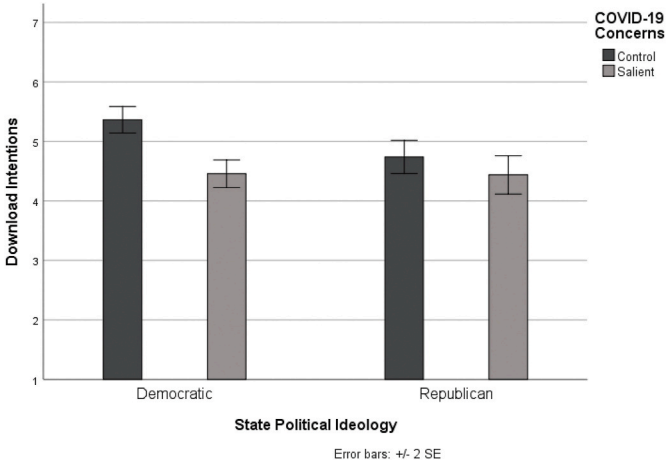

Fig. 6. Experiment 3: Download intentions as a function of state political ideology and COVID-19 concerns.

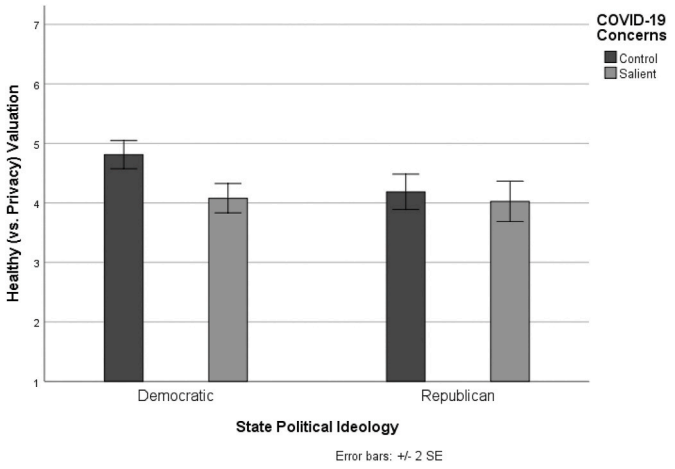

Fig. 7. Experiment 3: Health (vs. Privacy) valuation as a function of state political ideology and COVID-19 concerns.

those in Democratic states ($M = 2.79$, SD = 1.34). This is not surprising. But there was no main effect of salient disease concerns, F (1, 1001) = 0.16, $p = .73$. There was likewise no two-way interaction crossing salient disease concerns and state political ideology, F (1, 1001) = 0.001, $p = .98$. Because we found a main effect of state political ideology on trust, we re-ran our moderated mediation model with trust as a co-variate. The index of moderated mediation held and remained significant, estimating at 0.12 (*S.E.* = 0.05; 95% CI: 0.002, 0.25).

5.3. Discussion

These results further support our proposed mechanism. We once again find, this time in the United States of America, that salient disease concerns reduce willingness to adopt contact tracing apps in the COVID-19 pandemic context. We also identify greater valuations of personal privacy as the likely explanation. Previously, in Experiment 2, we found that greater social conservatism arose because of salient disease concerns. Here, we find that greater concerns about personal privacy specifically arises because of salient disease concerns.

Intriguingly, and in-line with our expectations, the impact is only apparent in Democratic states but weakens among Republican states. This complements Experiment 2 by finding that disease concerns affect personal privacy and willingness to use contact tracing apps by eliciting greater conservatism. We do not measure conservatism here, but rather compare Democratic with Republican states. Because Democratic states are less conservative with which to begin, salient COVID-19 concerns increase their conservatism, which would include greater personal privacy concerns. But because Republican states are already conservative, any further effect of disease concerns on privacy and willingness to adopt contact tracing apps should be minimal. Indeed, if conservatism were *not* the mechanism (which is possible because in Experiment 2 our measure of social conservatism may have co-varied with the "true" mediator), then the impacts of disease concerns on personal privacy valuations as well as willingness to adopt contact tracing apps should arise for both Democratic and Republican states.

One particular note about our measure of personal privacy is that we assess it by having participants trade it off with benefits to public health. Indeed, contact tracing apps can support public health by facilitating officials' contact tracing but at the same time can potentially invade one's personal movements and lives. In most conceptualizations of privacy within health technology adoption (Conger et al., 2013; Eng & Lee, 2013; Fox & Connolly, 2017; Wu et al., 2007), privacy needs to be weighted against health, whether public or personal; thus, the measure of privacy here as one involving trade-offs is consistent with existing literature.

6. General Discussion

Intuitively, when disease concerns are high, people should be more concerned about their health, which would presumably increase their willingness to use contact tracing apps designed to do so, even at the potential cost to their personal privacy. However, in the current research, we draw from evolutionary research to make a counter-intuitive hypothesis. Because disease concerns trigger a behavioral immune system (Ackerman et al., 2018; Schaller & Park, 2011), this includes activation of social conservatism generally (Horberg et al., 2009; Murray & Schaller, 2012; Tyler et al., 2009) that would include greater concerns about one's own personal privacy (Jost et al., 2009; Margulis, 1977; Milne & Rohm, 2000; Viguerie, 2013; Wartenberg & Thompson, 2010; Westin, 2003). Taking these findings in the literature together we thus propose that disease concerns would actually increase such concerns.

We demonstrate this using the COVID-19 pandemic to explore why uptake of contact tracing apps is slow worldwide. In Experiment 1, we show that salient COVID-19 concerns within the French context reduce intentions to download and use StopCovid (Onishi & Méheut, 2020). We replicate this in Experiment 2 in the Australian context and show that social conservatism can explain these counter-intuitive results (Meade, 2020). Lastly, in our Experiment 3 in the American context, salient COVID-19 concerns decrease intentions to use a hypothetical contact tracing app in the United States because of greater privacy concerns. This effect primarily emerges in Democratic but not in Republican states, thus implicating the role of social conservatism.

6.1. Theoretical contributions

Our research advances theory in three ways. First, while there is evidence that disease concerns increase social conservatism, the evidence is indirect (Ackerman et al., 2018). For example, disease concerns increase group-norm conformity (Murray & Schaller, 2012) and an aversion to moral standard violations (Horberg et al., 2009; Tyler et al., 2009), both of which indicates greater social conservatism, but we are the first to directly show, in Experiment 2 with an Australian sample, that salient disease concerns increase support for socially conservative policies and views. Second, we advance work on mobile health app and/or technology adoption, given that such apps are typically only of pertinence during pandemics, and thus research on their adoption is limited and has primarily been of interest during the coronavirus pandemic (Bachtiger, Adamson, Quint, & Peters, 2020; O'Callaghan et al., 2020; Walrave, Waeterloos, & Ponnet, 2020). Our findings reveal that willingness to use contact tracing apps go beyond existing technology adoption models by highlighting the role of concerns regarding privacy, which are not part of such models (Davis et al., 1989; Venkatesh et al., 2003). Experiment 3 reveals the role of privacy concerns in explaining why salient COVID-19 concerns reduce the willingness to download a contact tracing app in the American context.

Third, more importantly, we document a barrier to the adoption of contact tracing apps that are designed to protect one's and the public's health. Indeed, why has uptake been so slow? Our findings in Experiment 3 implicate the role of privacy concerns, which are greater when concerns about COVID-19 are high. Importantly, the experiment reveals that these concerns are weighted more than concerns about personal and public health during the coronavirus pandemic. Intuitively, during such times and public health crises, concerns about health should be paramount. But we show that this is an incorrect assumption since disease concerns in fact, via the behavioral immune system and social conservatism (Experiment 2), heighten the primacy of personal privacy concerns. A heightening of such concerns, coupled with the potential invasion of privacy due to contact tracing apps, sheds theoretical insights into a conundrum that eludes not only scholars but also practitioners.

6.2. Policy implications

Our findings offer insights into public policy on how contact tracing apps ought to be promoted and conveyed in health communications. Again, we are cognizant of the fact that contact tracing apps are little needed *outside* of pandemics, and so when they are introduced or promoted, disease concerns *ought* to be high. However, our results highlight the need to reduce people's concerns about personal privacy especially in times of pandemics, instead of simply relying on an appeal to public health or even with the incentive of easing lockdown restrictions, as in the case of Australian Prime Minister Scott Morrison. Indeed, our findings in Experiment 3 suggest that reducing the privacy concerns associated with contact tracing apps is especially paramount during public health crises. There are many ways to promote and communicate contact tracing apps. Highlighting the benefit in protecting public or personal health is beneficial but likely not as beneficial as ensuring that such apps also protect one's privacy, or that personal information is not captured or only utilized under stringent measures as during times that involve public health emergencies.

Another implication of our findings is that contact tracing apps might be better adopted *outside* of or *before* pandemics. This is suggested by all three experiments in which adoption of contact tracing apps are, relatively, greater when disease concerns are low. In a way, this sounds paradoxical, as there is no need for these apps when there is no disease spreading. But, contact tracing apps can be promoted as a way to promote public health *in the future*. For example, after the novel coronavirus pandemic, governments can potentially continue to promote contact tracing apps to ensure public health in the future. During such a time, disease concerns are low, and so concerns about personal privacy would be less of a concern, per our hypothesis. Indeed, personal privacy *is* generally a concern, but it becomes even *more* of a concern when disease concerns are salient, during a time when one would intuit that public health would trump privacy concerns.

Our findings, especially in Experiments 2 and 3, suggest furthermore that contact tracing apps ought to be targeted properly, and messages designed appropriately. As the experiment demonstrates, the effect of salient novel coronavirus concerns on reducing tracing app uptake intentions is in fact strongest in U.S. states that are Democratic. This is not only consistent with our theorized role of conservatism, but it also suggests that, during a pandemic, when disease concerns are high, the potential unsuccessful efforts at promoting tracing apps may be greatest in these areas. In that experiment, we use state-level data as a proxy for political views. Certainly, we can directly capture political views by asking for them directly from participants; however, using state-level data has a practical benefit. Indeed, it is not practical for public health officials to find individual-level data or use it efficiently in message conveyance or to target each person individually. This is where state-level data becomes beneficial, as our findings indicate that salient disease concerns increase privacy concerns and reduce willingness to adopt contact tracing apps *primarily* in Democratic areas. This implies that efforts at promoting contact tracing apps in Democratic states when disease concerns are high versus low ought to also differ whereas efforts at promoting these same apps in Republican states, in which disease concerns are high versus low, may not need to differ. Likewise, efforts at reducing privacy concerns could be communicated on networks such as CNN that is primarily aimed at liberals more so than on FOX News that is primarily aimed at conservatives.

Our findings are focused on COVID-19 tracing apps but may also offer some conceptual and practical considerations for other uses of technology in public health management. "E" or electronic health records are becoming the norm in many countries, but like tracing apps there are worries about invasion of one's personal privacy (Hsia, Chiang, Wu, Teng, & Rubin, 2019; Park & Shin, 2020). It is likely that promoting electronic health records when someone has a disease or is ill otherwise may actually lower the person's uptake of a platform that is aimed at protecting their health. Similarly, fitness devices are also known to invade privacy. However, because such "wearable" devices are not dependent on pandemics, privacy concerns may be low, explaining their greater adoption compared to e-health records and m-health technologies (Conger et al., 2013; Eng & Lee, 2013; Fox & Connolly, 2017). We focus strictly on the COVID-19 pandemic but there is reason to believe that salient disease concerns can reduce uptake of other health technologies—a claim that further research can confirm.

6.3. Limitations to current studies

However, there are several limitations that we need to acknowledge. First, we recruit participants in France, Australia, and the United States, showing robustness of our effects regardless of cultural context and sample. Conceptually, disease concerns trigger the behavioral immune system, an evolutionary adaptive mechanism that is independent of culture, and so our effects should be robust to culture. However, there are cross-cultural differences in concerns regarding privacy that warrant further attention. Some cultures, such as China, may be more open to the collection and monitoring of personal data from the government, compared to others, such as the Europe or the United States. Indeed, our samples are more alike than different, and so replication of our effect and especially the role of privacy concerns is needed.

Relatedly, a user's age has also been demonstrated as one moderator in concerns about privacy (Wu et al., 2007), insinuating that our effects can also be moderated by age. This was not our focus and so we do not compare, say, younger adults with older adults; thus, further research can look at the possible moderating role of age. Finally, our findings may apply to other contexts besides contact tracing apps such as electronic health records and wearables, but we do not have any data to support this conclusion unequivocally. Therefore, further work should test for age as a potential moderator for our effect, and should examine whether salient disease concerns would influence adoption of other m-health technologies. Our research, we believe, provides a theoretical framework to explore such important questions at the intersection of personal privacy, technology, and public health.

There are also other limitations of the current research. This includes the fact that we rely predominantly on self-report and online data collection that may provide a biased participant pool and lead to concerns about socially-desirable responding. But in Experiment 3, our use of Mechanical Turk is consistent with other work in the social sciences showing that participants from this online crowdsourcing platform are largely reliable, and results on key social scientific metrics are in line with nationally-representative samples (Paolacci & Chandler, 2014; Rouse, 2015). Thus, further work should use non-crowdsourcing and non-student samples to test our effect. And, although we conduct our studies in three countries to show that our posited effects are not restricted to, say, only France, there are differences between the contact tracing apps that may be unique yet we did not consider. For example, in some countries, the apps' Bluetooth function collect "ping" data from a nearby smartphone within 6 feet while other apps use a smaller or wider distance and some countries only collect such data if contact were 15 min or longer while other countries use a different time period.

And speaking of privacy concerns, some countries are more open to governmental collection of such data, such as South Korea and China. We only focus on participants from Western cultures where attitudes are generally against governmental intrusion, and so our premise should be tested in other countries in which attitudes differ from those in the West. We also did not ask if participants already have COVID, either at the time of the experiment or before. It is likely that an extant diagnosis may increase willingness to use such apps given stronger concerns about health. Thus, further work should, besides replicating our effect in other cultures, examine the specific attributes of contact tracing apps and see if they would moderate the effect. For example, citizens in one country may consider data collection within 5 min to be more of a privacy concern than data collection within 15 min. This would suggest that specific features of contact tracing apps (in this case, how long it takes

for a "ping" to be recorded) might play a role in determining the extent to which personal privacy may be invaded.

Critically, we only focus on concerns about governmental intrusion into personal privacy as a potential mechanism. We do not assess others, which may offer a more holistic picture of why salient COVID-19 concerns decrease willingness to use contact tracing apps. For example, contact tracing apps may be seen as difficult to use, or they do not see their effectiveness in facilitating contact tracing or in helping "flatten the curve." There may also be politically-based concerns. All of these concerns could potentially be heightened when COVID-19 concerns are salient, offering other rival accounts to our effects—but these can also be complementary to our hypothesis in the current research. Moreover, depression and other mental health symptoms may be relevant when even thinking of the novel coronavirus and devastating consequences on one's lives. Our focus is on advancing privacy concerns as a possible explanation in our hypothesized effects given their role as a barrier in adopting other health technologies (Wu et al., 2007), and so we hope that our work will instigate others on these important questions.

Credit author statement

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Appendix 1

As of December 2020, the following countries have either already introduced contact tracing apps or proposed:

1. Australia
2. Austria
3. Azerbaijan
4. Bahrain
5. Bangladesh
6. Brazil
7. Canada
8. China
9. Colombia
10. Croatia
11. Czech Republic
12. Denmark
13. Fiji
14. Finland
15. France
16. German
17. Ghana
18. Gibraltar
19. Hungary
20. Iceland
21. India
22. Ireland
23. Israel
24. Italy
25. Japan
26. Jersey
27. Jordan
28. Latvia
29. Malaysia
30. Nepal
31. Netherlands
32. New Zealand
33. North Macedonia
34. Norway
35. Portugal
36. Qatar
37. Russia
38. Saudi Arabia
39. Scotland
40. Singapore
41. Spain
42. Switzerland
43. Turkey
44. United Kingdom

APPENDIX 2

Political ideology for each U.S. state as of June 2020:

State	2016 Elect.	Governor	State Senate	State House
Alabama	Republican	Republican	Republican	Republican
Alaska	Republican	Republican	Republican	Coalition
Arizona	Republican	Republican	Republican	Republican
Arkansas	Republican	Republican	Republican	Republican
California	Democratic	Democratic	Democratic	Democratic
Colorado	Democratic	Democratic	Democratic	Democratic
Connecticut	Democratic	Democratic	Democratic	Democratic
Delaware	Democratic	Democratic	Democratic	Democratic
Florida	Republican	Republican	Republican	Republican
Georgia	Republican	Republican	Republican	Republican
Hawaii	Democratic	Democratic	Democratic	Democratic
Idaho	Republican	Republican	Republican	Republican
Illinois	Democratic	Democratic	Democratic	Democratic
Indiana	Republican	Republican	Republican	Republican
Iowa	Republican	Republican	Republican	Republican
Kansas	Republican	Democratic	Republican	Republican
Kentucky	Republican	Democratic	Republican	Republican
Louisiana	Republican	Democratic	Republican	Republican
Maine	Democratic	Democratic	Democratic	Democratic
Maryland	Democratic	Republican	Democratic	Democratic
Massachusetts	Democratic	Republican	Democratic	Democratic
Michigan	Republican	Democratic	Republican	Republican
Minnesota	Democratic	Democratic	Republican	Democratic
Mississippi	Republican	Republican	Republican	Republican
Missouri	Republican	Republican	Republican	Republican
Montana	Republican	Democratic	Republican	Republican
Nebraska	Republican	Republican	Unicameral nonpartisan	
Nevada	Democratic	Democratic	Democratic	Democratic
New Hampshire	Democratic	Republican	Democratic	Democratic
New Jersey	Democratic	Democratic	Democratic	Democratic
New Mexico	Democratic	Democratic	Democratic	Democratic
New York	Democratic	Democratic	Democratic	Democratic
North Carolina	Republican	Democratic	Republican	Republican
North Dakota	Republican	Republican	Republican	Republican
Ohio	Republican	Republican	Republican	Republican
Oklahoma	Republican	Republican	Republican	Republican
Oregon	Democratic	Democratic	Democratic	Democratic
Pennsylvania	Republican	Democratic	Republican	Republican
Rhode Island	Democratic	Democratic	Democratic	Democratic
South Carolina	Republican	Republican	Republican	Republican
South Dakota	Republican	Republican	Republican	Republican
Tennessee	Republican	Republican	Republican	Republican
Texas	Republican	Republican	Republican	Republican
Utah	Republican	Republican	Republican	Republican
Vermont	Democratic	Republican	Democratic	Democratic
Virginia	Democratic	Democratic	Democratic	Democratic
Washington	Democratic	Democratic	Democratic	Democratic
West Virginia	Republican	Republican	Republican	Republican
Wisconsin	Republican	Democratic	Republican	Republican
Wyoming	Republican	Republican	Republican	Republican

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