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Tracing-Technology Adoption During the COVID-19 Pandemic: The Multifaceted Role of Social Norms

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Tracing technology has been introduced as part of a broader COVID-19 containment strategy in many countries. However, little is yet known about the drivers and barriers to the adoption of tracing apps. Our theoretical framework integrates concepts from technology acceptance (i.e., perceived usefulness and ease of use), health protection (i.e., perceived threat), and social norms research (i.e., perceived norms). To understand the role of these perceptions in the decision process of people who hesitated to adopt the app (N = 327), we conducted a two-wave panel study after app release in Switzerland. We found that perceived usefulness and ease of use of the app, as well as perceived threat of COVID-19 were positively correlated with adoption intention, whereas perceived threat of data misuse was negatively correlated with it. Social norms played a multifaceted role: They were positively correlated with perceived usefulness of the app and adoption intention. Adoption intention, in turn, predicted app adoption 10 weeks later. We discuss theoretical and practical implications of these findings.

Keywords: contact-tracing app, technology acceptance, health protection motivation, social norms, COVID-19, longitudinal study

App-based contact tracing has been introduced as part of a broader COVID-19 containment strategy in several countries (Kahn, 2020a). The introduction of these apps was linked with the hope of controlling the pandemic while, at the same time, allowing the economic, political, and social system to recover. However, in most countries, the current uptake rates are too low to realize the full potential of contact-tracing apps as public health measures (Ferretti et al., 2020). In Switzerland, the official statistics

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reported only 1 million active apps one week after app release, which equals an acceptance rate of 12% of the population.[3] Simulation studies, however, estimated that app adoption by 80% of smartphone owners, or about 60% of the overall population, is required to suppress the pandemic (Hinch, Probert, Nurtay, Kendall, & Wymant, 2020). These numbers demonstrate the necessity to learn more about the people who hesitated to download and use the app (Geber & Friemel, 2021). More specifically, a better understanding about the drivers and barriers to app adoption is required to increase app-uptake rate in the population.

Research on predictors of app adoption is scarce, as digital contact tracing was introduced only recently in most countries in response to the COVID-19 pandemic. Most research followed a descriptive approach and focused on app-related privacy concerns as barriers to app adoption (Abuhammad, Khabour, & Alzoubi, 2020; Altmann et al., 2020; Jansen-Kosterink, Hurmuz, den Ouden, & van Velsen, 2020; Thomas, Michaleff, Greenwood, Abukmail, & Glasziou, 2020). Given that contact-tracing apps are digital technologies as well as health protection measures, a comprehensive understanding of tracing-app adoption needs to take a boarder perspective and combine technology acceptance (Davis, 1989) and health protection research (Rogers, 1975; Rosenstock, Strecher, & Becker, 1988). Furthermore, the use of the app is a cooperative behavior (Diekmann, 2020) because its effectiveness depends on widespread app adoption in the population (Ferretti et al., 2020; Hinch et al., 2020), which points to the need to pay special attention to social norms.

The present study integrated a set of app-related perceptions from technology acceptance (i.e., perceived usefulness, perceived ease of use) and health protection theories (i.e., perceived threat about COVID-19 and data misuse) with a differentiated perspective on normative conduct. The latter includes the distinction between perceived *descriptive* and *injunctive norms* about app adoption (Cialdini, Reno, & Kallgren, 1990) as well as normative perceptions pertaining to the *general population* and the *personal environment* (Patrick, Neighbors, & Lee, 2012). The hypotheses on the influences of these app-related perceptions on tracing-app adoption among people who hesitated to adopt the app were tested based on a two-wave online survey conducted after the release of the tracing app in Switzerland.

Drawing on its integrative theoretical framework and methodological setup, this study provides knowledge about the relative importance of app-related perceptions as predictors of app adoption. The longitudinal study design and the timing of data collection after the app release allowed learning more about the reasoning process of people who hesitated to adopt the app in the first days after its release. The study's findings are of practical relevance as they indicate which perceptions of the most crucial part of the population (people who had not downloaded the app) should be addressed by communication strategies to increase app-uptake rate in the overall population.

Tracing Apps as Public Health Measures During the COVID-19 Pandemic

The primary objective for contact-tracing apps is to stop COVID-19 from spreading further by complementing the conventional tracing of transmission chains. Its basic function is to immediately inform people who have potentially been exposed to the coronavirus so they can test and quarantine themselves

[3] This is only a rough and conservative estimate because the data protection measures do not allow any identification and differentiation between users.

and thereby avoid infecting others. In Switzerland, the SwissCovid app uses Bluetooth technology to exchange randomly generated IDs with other apps. As most other contact-tracing apps introduced worldwide (Kahn, 2020b), the SwissCovid app follows the principle of "privacy by design" (Cavoukian, 2010), meaning that privacy and security protections are built into the technology design to ensure data security (rather than only counting on responsible use).

The SwissCovid app was released on June 25, 2020. Data from the Federal Statistical Office (2020) documented a fast diffusion of app adoption during the first week after its release. However, despite the efforts to design the app to be user friendly and privacy protecting as well as health authorities' calls for solidarity, the numbers of active apps started to stagnate at about 1 million after seven days.[4] In other words, a significant part of the population hesitated to adopt the tracing app (Geber & Friemel, 2021).

Tracing-App Adoption

This study aimed to learn more about the app-related perceptions of people who hesitated to adopt the app, specifically about the weighting of these perceptions in their reasoning process. We therefore followed the reasoned action approach assuming that people's behavior follows reasonably from behavior-related perceptions and intentions (Ajzen & Fishbein, 2005; Fishbein & Ajzen, 1975). To capture relevant perceptions, we considered that tracing apps are digital technologies, health protection measures, and cooperative behaviors (as the effectiveness of the app depends on widespread adoption) and integrated the most central constructs from technology acceptance, health protection, and social norms research. Concretely, our framework combines (1) perceived usefulness and perceived ease of use from the technology acceptance model (TAM; Davis, 1989), (2) perceived threat (disease- and app-related) as discussed in the protection motivation theory (PMT; Rogers, 1975) and the health belief model (HBM; Rosenstock et al., 1988), as well as (3) perceived descriptive and injunctive norms (population- and personal-environment related) from social norms research (Cialdini et al., 1990; Rimal & Real, 2005). We note that—though rooted in different research traditions (i.e., technology acceptance vs. health behavior)—the TAM and the HBM/PMT have significant overlaps in their constructs. For example, TAM's concept of perceived usefulness can be regarded as equivalent to PMT's component of response efficacy and HBM's component of perceived benefits; TAM's perceived ease of use shows parallels with PMT's self-efficacy. These equivalents underline the basic compatibility of the theories and the sufficiency of the constructs that were integrated in the present study. In the following, we refer to the theoretical and empirical foundations of these constructs and derive hypotheses on their influence on tracing-app adoption among people who hesitated to adopt the app.

Perceived Usefulness and Perceived Ease of Use

Perceived usefulness and perceived ease of use are the main constructs of the TAM (Davis, 1989). The model has been extended over the years, resulting in updated and extended versions of the TAM, such as the TAM2 (Venkatesh & Davis, 2000) and TAM3 (Venkatesh & Bala, 2008), or the unified theory of

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acceptance and use of technology (UTAUT; Venkatesh, Morris, Davis, & Davis, 2003). However, perceived usefulness and perceived ease of use have remained at the core of the model and are supposed to be the primary predictors of behavioral intention. It is further suggested that perceived ease of use is a direct determinant of perceived usefulness because the easier a technology is to use, the more effectively it can be applied (Venkatesh & Davis, 2000). Meta-analyses have provided accumulative evidence for these relationships across various technologies (King & He, 2006; Schepers & Wetzels, 2007).

Applied to contact-tracing technology during the COVID-19 pandemic, perceived usefulness refers to the perception of how useful the contact-tracing app is to help the user identify a potential infection, and perceived ease of use refers to the degree to which a person believes that using the contact-tracing app would be easy and free of effort in everyday life (Davis, 1989).[5] Empirical findings about contact-tracing apps support the assumption that positive expectations concerning the app's performance and benefits (i.e., perceived usefulness) are an important predictor of app-uptake intention (Kukuk, 2020; Walrave, Waeterloos, & Ponnet, 2020a, 2020b). Also, perceived ease of use has been shown to have a positive effect on the intention to adopt the app (reported as "facilitating conditions" in Walrave et al., 2020b, or "self-efficacy" in Walrave et al., 2020a). Following the theoretical and empirical findings in line with the TAM, we assumed that both perceived usefulness and perceived ease of use were positively correlated with the intention to adopt the app and, further, that perceived ease was also correlated with usefulness perceptions. Formally, we stated the following hypotheses:

H1–H2: Perceived usefulness (H1) and perceived ease of use (H2) of the contact-tracing app are positively correlated with the intention to adopt the app.

H3: Perceived ease of use of the contact-tracing app is positively correlated with the perceived usefulness.

Perceived Threat of COVID-19

Perceived threat is an important predictor of health protection behavior (Prentice-Dunn & Rogers, 1986), as suggested in the HBM (Rosenstock et al., 1988) and the PMT (Rogers, 1975). In both theories, perceived threat is differentiated into perceived susceptibility (referred to as vulnerability in PMT) and perceived severity of the health threat. Meta-analyses have demonstrated the significant role of both threat perceptions about health protection behavior (Floyd, Prentice-Dunn, & Rogers, 2000).

We thus differentiated between perceived susceptibility as the perception of the risk of being infected with COVID-19 and perceived severity as the perceived magnitude of a negative health outcome of a COVID-19 infection. While in a study among 406 participants in Germany, susceptibility and severity perceptions did not affect the intention to adopt the tracing app (Kaspar, 2020; see also Walrave et al., 2020a), a survey conducted among 238 Dutch adults revealed that fear of COVID-19 was a correlate of the intention to use the app (Jansen-Kosterink et al., 2020). Given the strong theoretical and empirical findings

[5] We note that in the current case perceived usefulness may also refer to the social level and cover perceptions of the technology's usefulness in controlling the pandemic. However, following the original idea of the TAM, we only refer to perceptions of the usefulness for the individual (Davis, 1989).

on threat perceptions as motivations for health protection behavior, we assumed both to be correlated with the intention to adopt the app and stated the following hypotheses:

H4–H5: Perceived susceptibility to (H4) and severity of (H5) COVID-19 are positively correlated with the intention to adopt the app.

Perceived Threat of Data Misuse

Given that privacy threat was a central feature of the debate around the tracing app (e.g., Guinchard, 2020), we also included the perceived threat of data misuse in our model. This is in line with previous studies that applied the threat dimension of the HBM or PMT to data privacy issues following the idea that the provision of personal data can be regarded as risky behavior (Banks, Onita, & Meservy, 2010; Woon, Tang, & Lowe, 2005). Specifically, we differentiated between perceived susceptibility to and perceived severity of data misuse (Kaspar, 2020). Descriptive studies on tracing app acceptance showed that privacy concerns were mentioned as reasons for not downloading the app (Abuhammad et al., 2020; Altmann et al., 2020; Jansen-Kosterink et al., 2020; Thomas et al., 2020). Correlational studies further demonstrated that such concerns negatively influenced app-uptake intention (Walrave et al., 2020b), with both susceptibility and severity being significant predictors (Kaspar, 2020). Accordingly, we stated the following hypotheses:

H6–H7: Perceived susceptibility to (H6) and severity of (H7) data misuse due to the contact-tracing app are positively correlated with the intention to adopt the app.

Social Norms

Social norms have been included later in technology acceptance research (TAM2; Venkatesh & Davis, 2000; UTAUT; Venkatesh et al., 2003) in the form of subjective norms, which refer to a person's perception that important others expect him or her to perform the behavior in question (Ajzen & Fishbein, 2005). Venkatesh et al. (2003) and Venkatesh and Bala (2008) expected subjective norms to influence intention and perceived usefulness and provided different rationales for these effects (e.g., compliance-, internalization-, and information-based mechanisms).

To tap the meaning of social norms and their influences comprehensively, the current social norms research distinguishes between perceived *descriptive norms* and *injunctive norms*, as introduced by Cialdini and colleagues (1990). Descriptive norms refer to the prevalence of a behavior; injunctive norms show parallels to subjective norms and pertain to the social approval of the behavior (Cialdini et al., 1990). While descriptive norms are supposed to be influential because they provide evidence about what is likely to be effective ("information-based influence"), injunctive norms are influential because of people's motivations for affiliations with referents ("affiliation-based influence"; Rimal & Lapinski, 2015; see also Deutsch & Gerard, 1955).

We combined the distinction of descriptive and injunctive norms with the idea of hierarchical norms (Patrick et al., 2012) suggesting that normative perceptions can refer to social groups at different levels, such as the population and the personal environment. Both were supposed to be relevant referents in the

present case of app adoption during the COVID-19 pandemic for different reasons: The population is a relevant group, as the pandemic affects the whole society and the success of health protection measures about communicable diseases depends on far-reaching compliance in the population. This particularly applies to the use of the contact-tracing app, which can be understood as a cooperative behavior (Diekmann, 2020): The more people use the app, the more effective it is. This was not only scientific knowledge (Hinch et al., 2020) but also a formula that has been communicated in the news media (e.g., Kahn, 2020b). As follows, we expected the population norms to be particularly influential in the case of the adoption of the contact-tracing app, compared with technologies that are exclusively of individual benefit. The members of the personal environment, on the other hand, were assumed to be influential because they are those with whom individuals identify, to whom they want to belong, and who are trusted. This reference group is the most often used in social norms research (Shulman et al., 2017) and has been shown to be normatively influential across various behaviors (Manning, 2009).

Against this background, the study examined the importance of different norm facets (i.e., descriptive, injunctive) about two referent groups (i.e., population, personal environment). This results in four distinct norm perceptions: perceived descriptive and injunctive norms of app adoption relating to the population as well as perceived descriptive and injunctive norms pertaining to the personal environment. Based on the accumulative empirical evidence of normative effects on perceived usefulness and behavioral intention in technology acceptance research (Schepers & Wetzels, 2007) and health behavior research (Sheeran et al., 2016), we stated the following hypotheses:

H8a–d: Perceived descriptive norms (H8a) and injunctive norms about the general population (H8b), as well as perceived descriptive norms (H8c) and injunctive norms about the personal environment (H8d), are positively correlated with perceived usefulness.

H9a–d: Perceived descriptive norms (H9a) and injunctive norms about the general population (H9b), as well as perceived descriptive norms (H9c) and injunctive norms about the personal environment (H9d), are positively correlated with the intention to adopt the app.

Intention and Behavior

In line with the reasoned action approach (Fishbein & Ajzen, 1975), the TAM follows the idea that "intention to perform a behavior is the closest cognitive antecedent of actual behavioral performance" (Ajzen & Fishbein, 2005, p. 188). In the present case, the intention reflects people's motivation to install and use the contact-tracing app and results from the abovementioned perceptions (i.e., perceived usefulness, perceived ease of use, perceived disease- and app-related threat, perceived social norms). Given the evidence for the predictive validity of behavioral intentions as demonstrated in the reasoned action tradition (Armitage & Conner, 2001; McEachan, Conner, Taylor, & Lawton, 2011) but also in the TAM tradition (Schepers & Wetzels, 2007), we assumed that the stronger the intention for app adoption, the more likely is actual adoption. The hypothesis was as follows:

H10: The intention to adopt the contact-tracing app predicts the adoption of the app.

Methods

Sample

Our hypotheses were tested based on a two-wave online survey in the German-speaking part of Switzerland. The first survey wave (t1) was conducted one week after the release of the app, in July 2020. The sample was stratified by gender and age to increase the variance across these sociodemographic subgroups. The second wave of data collection (t2) was realized 10 weeks later in September 2020. Of the respondents who participated at t1 (N = 1,076), 81% participated at t2 (N = 875). The analysis of respondents lost to attrition did not show a systematic bias in panel mortality regarding gender, $t(1074) = -.870$, $p = .384$, and app use, $t(1074) = -1.270$, $p = .204$. However, we found a significant difference with regard to age, $t(1074) = -2.136$; $p = .033$, with those lost to attrition being slightly younger (M = 44.62, SD = 17.84) than respondents who participated in both waves (M = 47.56, SD = 17.54). As this difference was small and age did not play a significant role in the further analysis, we assumed this bias would not affect the reliability of our results.

At t1, we asked participants the question of whether they have installed and currently use the contact-tracing app by providing the following answer options: 1 = *yes, and I use it* (n = 584); 2 = *yes, but I have deactivated it* (n = 22); 3 = *no, because I haven't installed it (yet)* (n = 407); 4 = *no, because I've uninstalled it already* (n = 25); and 5 = *no, because I do not have a smartphone* (n = 38). To understand how the abovementioned app-related perceptions guided the decision process of people who did not belong to the early adopters (Rogers, 2003), we tested our hypotheses based on those survey participants who were smartphone users and had not yet downloaded the app at t1. Of these 407 participants, n = 327 participated at t2. Hence, our analysis was based on this subsample (n = 327), which included 57% females and had an age range of 16 to 80 years (M = 47.02, SD = 17.07).

Measures

App adoption was measured at t2 by the same question as used at t1 and described above. At t2, we used this variable to construct the dependent variable of app adoption, which was defined as having the app installed and using it. This computed variable had the values 1 = *yes and I use it* and 0 = *no* (combining the other options). Of the sample, and thus of those who had not installed the app at t1, 16% reported to have adopted the tracing app at t2.

The intention to adopt the app was measured at t1 in the form of self-prediction. Concretely, we asked participants the following question: "How likely do you think it is that you will install and use the tracing app in the future?" (scale: 1 = *very unlikely* to 5 = *very likely*; M = 2.64, SD = 1.38).

All app-related perceptions were measured at t1. Except for perceived descriptive norms, all constructs were assessed by three items on a 5-point scale ranging from 1 = *do not agree at all* to 5 = *fully agree* (see Table 1). The wording of the perceived usefulness and perceived ease of use items was oriented toward the measurements applied in technology acceptance research (e.g., Davis, 1989; Venkatesh et al., 2003). The items for perceived susceptibility and severity related to COVID-19 and data misuse followed

definitions and measures in health protection research (e.g., Prentice-Dunn & Rogers, 1986). In line with its definition, the perceived injunctive norms were assessed by perceived social approval statements, with perceptions relating to the personal environment and to the Swiss population (Rimal & Lapinski, 2015). Perceived descriptive norms were measured as the perceived prevalence of app adoption by asking respondents to assess the percentage of the population and personal environment that currently uses the tracing app ("What do you think is the percentage in the population and in your personal environment that currently uses the SwissCovid app?"; scale: percentage; population: *M* = 30.82, *SD* = 18.08; personal environment: *M* = 23.70, *SD* = 20.83).

Table 1. Measures of Latent Variables.

Concept and Items	*M* (*SD*)	Std. Loadings	α
Perceived usefulness (PU)			.84
PU1. If I use the tracing app, it helps me to recognize a possible infection at an early stage.	3.13 (1.21)	.756	
PU2. When I use the tracing app, I am reliably informed of the possibility of infection.	3.05 (1.15)	.881	
PU3. The tracing app reliably warns me if I was exposed to a risk of infection.	3.03 (1.11)	.797	
Perceived ease of use (PE)			.67
PE1. It's very easy for me to install the tracing app.	3.45 (1.37)	.519	
PE2. I trust myself to use the tracing app without further ado.	3.76 (1.23)	.686	
PE3. I can use the tracing app in everyday life without any problems.	3.19 (1.35)	.698	
Susceptibility to COVID-19 (SUC)			.68
SUC1. The risk is high that I will get COVID-19.	2.44 (1.03)	.921	
SUC2. It is likely that I will get COVID-19.	2.42 (0.99)	.428	
SUC3. I think it is unlikely that I will get COVID-19.*	2.98 (1.20)	.363	
Severity of COVID-19 (SEC)			.87
SEC1. If I get COVID-19, it has serious consequences for my health.	3.11 (1.28)	.802	
SEC2. Illness from COVID-19 would have far-reaching negative consequences for me.	3.14 (1.31)	.832	
SEC3. A COVID-19 infection would be bad for me.	3.26 (1.28)	.877	
Susceptibility to data misuse (SUD)			.78
SUD1. There is a high risk that my data can be misused if I use the tracing app.	2.75 (1.32)	.858	
SUD2. It is likely that the tracing app collects too much data about me.	3.05 (1.33)	.780	
SUD3. It is unlikely that the tracing app makes private information accessible to others.*	2.96 (1.27)	.546	

Severity of data misuse (SED)			.80
SED1. If the data recorded by the app were misused, it would have serious consequences for me and my privacy.	2.97 (1.35)	.770	
SED2. If the tracing app collected too much data about me, it would be bad for me.	3.29 (1.40)	.761	
SED3. If private information were made available to others via the tracing app, it would have negative consequences for me.	3.15 (1.35)	.743	
Injunctive norm population (INPO)			.68
INPO1. The Swiss population thinks it is important to use the tracing app.	3.00 (0.87)	.761	
INPO2. Swiss people think it's ok *not* to use the tracing app.*	3.32 (1.00)	.398	
INPO3. The Swiss population is generally positive about the tracing app.	3.09 (0.85)	.828	
Injunctive norm personal environment (INPE)			.74
INPE1. My social environment thinks it is important to use the tracing app.	2.78 (1.09)	.851	
INPE2. People in my social environment think it's ok *not* to use the tracing app.*	3.22 (1.14)	.413	
INPE3. My social environment is generally positive about the tracing app.	2.94 (1.06)	.891	

Note. n = 327; confirmatory factor analysis with maximum likelihood estimator; the residual variances of the items INPO1/INPE1, INPO2/INPE2, INPO3/INPE3 were allowed to be correlated; $\chi^2(221) = 305.330$; p = .000; CFI = 0.973; RMSEA = .034; 90% CI [.024, .043]; SRMR = .052; scale: 1 = *do not agree at all*, 5 = *fully agree*; * = items were recoded; *M* = arithmetic mean; *SD* = standard deviation; Std. loadings = standardized factor loadings; α = Cronbach's alpha.

Analysis

As a first step, we performed a confirmatory factor analysis using the maximum likelihood (ML) estimator to test our measures for the app-related perceptions. As we used the same items for the measurement of the population and the personal environment-related injunctive norms, the residual variances of the items with the corresponding wording were allowed to be correlated (i.e., items INPO1/INPE1, INPO2/ INPE2, INPO3/INPE3 in Table 1). The fit indices revealed a good fit for the measurement model (Hu & Bentler, 1999): $\chi^2(221) = 305.330$, p = .000, CFI = 0.973, RMSEA = .034, 90% CI [.024, .043], SRMR = .052. Overall, the measurements also showed good internal consistencies, with some dimensions, however, ranging at the lower end of acceptable reliability (i.e., perceived ease of use, susceptibility to COVID-19, injunctive norm population).

Second, we tested the relationships as hypothesized in *H1* to *H10.* We estimated a structural equation model (SEM) using ML to test all hypotheses simultaneously (see Figure 1). The app-related perceptions as well as the intention were included at t1 and app adoption at t2. The initial fit of the SEM was $\chi^2(313) = 529.012$, p = .000, CFI = 0.937, RMSEA = .046, 90% CI [.039, .053], SRMR = .075. Modification indices suggested the inclusion of covariances among the residuals of the social norm facets.

The modified SEM showed a good fit to the data (Hu & Bentler, 1999): $\chi^2(309) = 431.269$, $p = .000$, CFI = 0.966, RMSEA = .035, 90% CI [.027, .042], SRMR = .060. We also ran a model including age and gender as control variables, but the model showed a worse fit, and neither intention nor adoption were associated with age and gender, which has also been shown in previous studies on tracing-app adoption (Kaspar, 2020). All analyses were conducted in R with the package lavaan (Rosseel, 2012). For the sake of replicability, we report a correlation matrix across all observed variables in the appendix (see Table A1; accessible at https://researchbox.org/506). The SEM is depicted in Figure 1. Only significant standardized coefficients are reported; further coefficients and additional information are reported in the appendix (see Table A2).

Results

Figure 1 reveals that the correlates explained about 41% of the variance in the intention to adopt the contact-tracing app. Both perceived usefulness and perceived ease of use turned out to be positively correlated with the intention, which is in line with *H1* and *H2.* We found, however, no support for *H3* that perceived ease of use was associated with usefulness perceptions.

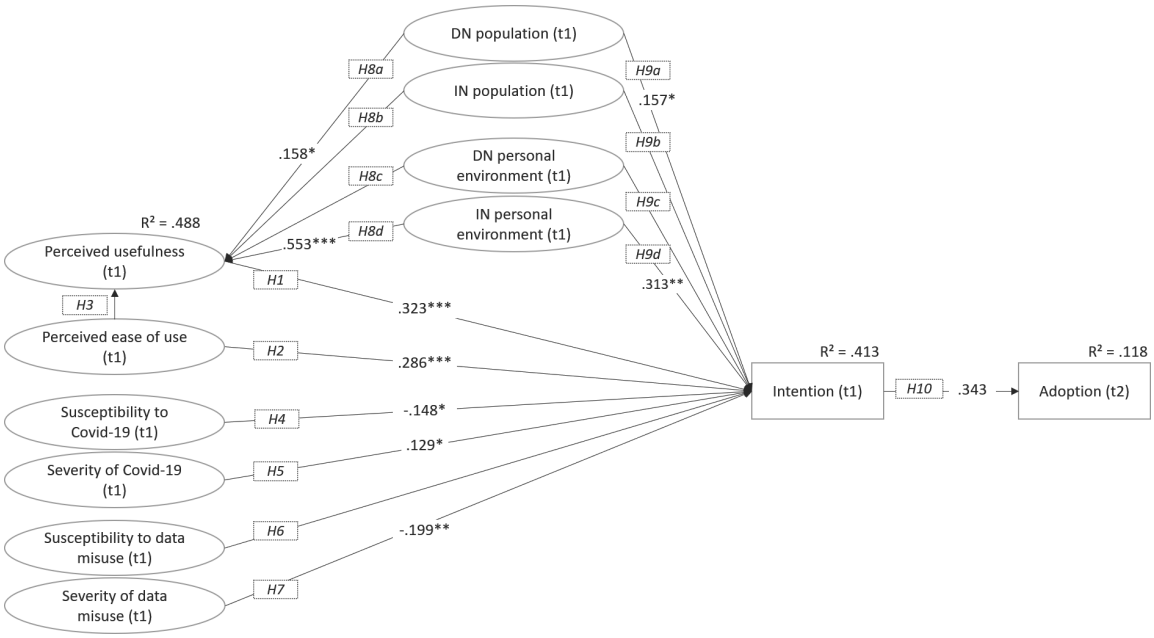

Figure 1. Structural equation model testing H1 to H10.

Note. $n = 327$; structural equation model with maximum likelihood estimator; $\chi^2(309) = 431.269$, $p = .000$, CFI = 0.966, RMSEA = .035, 90% CI [.027, .042], SRMR = .060; ellipses represent latent measures, and the measurement model is documented in Table 1; only significant paths are presented; scores represent standardized path coefficients; further coefficients as well as detailed information on them are reported in the appendix (Table A2, accessible at https://researchbox.org/506). DN = descriptive norm; IN = injunctive norm; R^2 = *r* square. ***$p \leq .001$. **$p \leq .01$. *$p \leq .05$.

Regarding the COVID-19-related threat perceptions, our results revealed a mixed pattern. In contrast to *H4*, susceptibility to COVID-19 was negatively correlated with app-use intention, while the perceived severity of COVID-19 was positively correlated with the intention to use the app (supporting *H5*). A similar pattern was found for the privacy threat due to the tracing app. While perceived susceptibility to data misuse was not related with the app-adoption intention (not corroborating *H6*), perceived severity of data misuse was correlated with reduced adoption intention, as assumed in *H7*.

The perceived prevalence of app use in the population (descriptive norm population) and perceptions about the social approval of app use in the personal environment (injunctive norm personal environment) were positively correlated with perceived usefulness, supporting *H8a* and *H8d*. Together, the descriptive norm about the population and the injunctive norm relating to the personal environment explained 49% of the perceived usefulness of the tracing app. Regarding *H9*, the results showed again that the descriptive norm in the population and the injunctive norm relating to the personal environment were correlates of the adoption intention, which was in line with *H9a* and *H9b*.

Last, our results corroborated *H10* that the intention to use the app at t1 predicted the actual adoption behavior 10 weeks later at t2; it accounted for 12% of the variance of actual adoption behavior.

Discussion

Contact-tracing apps are technologies, health protection measures, and cooperative behaviors at the same time. To address this complexity, the present study integrated technology acceptance (Davis, 1989), health protection (Rogers, 1975; Rosenstock et al., 1988), and social norms research (Cialdini et al., 1990; Rimal & Real, 2005). This synthesis turned out to be meaningful because we found concepts from technology acceptance (i.e., perceived usefulness and perceived ease of use) as well as from health protection theory (i.e., threat of the COVID-19 and data misuse), and social norms (i.e., descriptive and injunctive norms; both population- and personal-environment related) to be important factors in the reasoning process of people who hesitated to download the app. We discuss the most notable results as well as their theoretical and practical implications in the following sections.

Drivers and Barriers to Tracing-App Adoption

Perceived Usefulness and Perceived Ease of Use

Corroborating the core idea of the TAM (Davis, 1989), perceived usefulness and perceived ease of use turned out to be one of the most important correlates of the intention to use the contact-tracing app. This result is in line with previous studies, which show that performance expectancy (Kukuk, 2020; Walrave et al., 2020b)—a construct similar to perceived usefulness—was the most important correlate of adoption intention, and that self-efficacy—which is similar to perceived ease of use—was significantly correlated with app adoption (Walrave et al., 2020a). Further, in contrast to the typical finding of technology acceptance research (King & He, 2006; Schepers & Wetzels, 2007), perceived ease of use was not correlated with perceived usefulness. We assume that this is due to differences between the technologies examined in the present study and in previous technology acceptance research. The focus in technology acceptance research

has been primarily on technologies that support individuals in solving a concrete task, such as job-related tasks (Venkatesh et al., 2003). For such technologies, it is plausible that the individual perception of whether the technology can increase personal performance fundamentally depends on the perception that it is easy to use. In contrast to these task-related technologies, most contact-tracing apps do not provide an immediate experience of usefulness as the app is running unnoticed most of the time and will only alert the user in case of a potential infection.

Perceived Threat of COVID-19

Concerning the role of perceived threat of COVID-19, previous studies on tracing-technology adoption found mixed findings, with some showing no correlations (Kaspar, 2020; Walrave et al., 2020a) and others showing associations between fear of COVID-19 and the intention to use the app. In line with the HBM (Rosenstock et al., 1988) and the PMT (Rogers, 1975), the present study found that the perceived threat of the COVID-19 pandemic played an important role in the motivation to adopt the contact-tracing app. It is notable, however, that in contrast to the perceived severity of an infection, which supported app adoption, the perceived susceptibility to COVID-19 was correlated with reduced intention to use the app among people who hesitated to adopt the app. The rationale for this negative effect might be that people who perceived themselves to be vulnerable to a COVID-19 infection put themselves less frequently in situations in which a COVID-19 infection by (unknown) persons could occur (e.g., public transport, restaurants, or bars). At the same time, persons who perceived themselves as less vulnerable were more likely to participate in gatherings of unknown people and therefore were more dependent on this kind of contact tracing.

Perceived Threat of Data Misuse

The motivation to use a contact-tracing app has been further found to be influenced by the perceived threat of data misuse, which is in line with the results of Walgrave and colleagues (2020b), showing that app-related privacy concerns were correlated with reduced behavioral intention. However, in contrast to Kaspar (2020), we did not find that both perceived susceptibility and severity were correlated with adoption intention, but only that the subdimension of severity was a correlate of adoption intention. In other words, the perceived likelihood of data misuse did not seem to play a significant role in the decision of app adoption, while the perceived seriousness did. This may be partly explained by the privacy paradox, according to which some online users rarely make an effort to protect their data, while at the same time privacy of personal data is in general an important issue for them (Gerber, Gerber, & Volkamer, 2018). In line with the privacy paradox, our results showed that the perceived susceptibility to data misuse did not affect the decision for app adoption; in other words, there was a disconnect between the perceived likelihood of data misuse and the subsequent behavior (app adoption). It is only the degree of severity that seemed to imply a mismatch between costs (data misuse) and benefits for the users and that ultimately affects the decision for app adoption (toward no adoption of the app).

Social Norms

Our results suggest that—with regard to tracing-technology adoption—perceptions about descriptive norms matter at the level of the population, while perceptions about injunctive norms matter at the personal environment level. This indicates differences in how types of normative perceptions function at different levels.

Descriptive norms are said to be influential, as they inform about what relevant others do and will likely be an effective action (Cialdini et al., 1990). Our results suggest that, in the context of contact-tracing technologies, it is the population (and not the personal environment) that is the relevant reference group about this descriptive normative information. This reflects a rational consideration on the part of the (potential) app adopters, as the effectiveness of contact-tracing technologies fundamentally depends on widespread adoption in the whole population (and not in the personal environment). This rationale also becomes apparent in the correlation of the perceived descriptive norms in the population and the perceived usefulness of the app: The more that individuals perceive app use as being prevalent in the population, the higher the perceived usefulness. Thus, the influence of descriptive norms on the population level seems to be information based (Deutsch & Gerard, 1955; Rimal & Lapinski, 2015).

The influence of perceived injunctive norm in the personal environment, on the other hand, can be regarded as affiliation based (Rimal & Lapinski, 2015). As individuals identify with members of their personal environment and want to assure their belonging, they follow their perception of what ought to be done in this group. Further, this reference group also seems to serve as a trustworthy source of information, as indicated by the correlation between the perceived injunctive norm in the population and the perceived usefulness: The more individuals perceive that people in their personal environment approve the use of the app, the higher the perceived usefulness. This rationale is similar to the interpretation of Venkatesh and Davis (2000) on subjective norms' influence on perceived usefulness as internalization, a process by which one incorporates the referents' beliefs into one's own belief structure (Legros & Cislaghi, 2020).

Intention

Following the idea of the reasoned action approach (Fishbein & Ajzen, 1975) that the intention to perform a behavior is a close cognitive determinant of actual behavioral performance (Ajzen & Fishbein, 2005), we examined the extent to which the intention to use the app one week after the app release in Switzerland predicted actual app adoption 10 weeks later. Our results confirmed the intention–behavior relationship. However, we note that the effect is rather small ($\beta = .342$, $R^2 = 11.7$). We therefore tested for potential direct effects from app-related perceptions on behavior, but none of them was significant. This indicates that although intention is not a strong predictor of app adoption, it is the closest cognitive antecedent of this behavior. The rather weak intention–behavior relationship indicates that intentions changed during the time span of about 10 weeks (Ajzen & Fishbein, 2005), which might also be related to the study's focus on people who did not immediately adopt the app after its release, and thus on people who were rather unsure about app adoption.

Theoretical Implications

Our integrative framework and the corresponding results include a series of theoretical implications. Specifically, our study showed that privacy concerns (i.e., perceived threat of data misuse) were *not* the most crucial factor in the reasoning process of people who hesitated to use the tracing app. To fully understand privacy considerations underlying the adoption of data-driven health technologies, it is advisable to address perceptions about susceptibility to and severity of data misuse in a model.

Further, we lend the focus on the multifaceted role of social norms in tracing technology acceptance, as social norms have been widely ignored in research on pandemic-related health protection (Bish & Michie, 2010; Rimal & Storey, 2020) and have been considered only in a general way in technology acceptance research (i.e., in the form of an overall measurement of subjective norms; Schepers & Wetzels, 2007). That is all the more notable given that health protection behaviors carried out in response to a pandemic are inherently social: Their effectiveness depends on widespread compliance in the population, and/or protection behaviors are often visible to and thus potentially controllable by others (Rimal, Lapinski, Turner, & Smith, 2011; e.g., social distancing, Friemel & Geber, 2021). Hence, the inclusion of multiple social norm dimensions and referents is a theoretical advance to both lines of research (i.e., technology acceptance and pandemic-related health protection) and can help specify the mechanisms of social influences. Beyond the present case of contact-tracing technology for pandemic response, the differentiated consideration of social norms is likely to be relevant for any other communication technology that relies on positive network externalities (Shapiro & Varian, 2008). However, more research is needed to substantiate the patterns of normative influence found in the present study and to better understand the underlying mechanisms.

Practical Implications

The study's results on the various drivers and barriers to contact tracing adoption provide valuable insights for the implementation of such technologies as public health measures. Concretely, public communication campaigns may make use of the study's findings by focusing on the factors that revealed significant and substantial correlations with behavioral intention and that are potentially addressable by communication. More concretely, it appears to be advisable to emphasize the usefulness and simplicity of contact-tracing apps, as both factors are among the most important drivers of app adoption. Given the multifaceted role of social norms found in the present study, norms-based strategies and messages also seem to be promising means. However, as the current adoption rates are rather low in most countries, corresponding messages might emphasize *dynamic* norms and thus provide information about how referents' behavior and attitudes are changing over time (Sparkman & Walton, 2017). Our results thereby suggest that especially injunctive norms-based messages about app adoption that refer to the own social environment and targeted intervention might be effective. Further, such norms-based approaches might be supported by strategies of reaching out to early adopters to motivate them to encourage those in their personal environment to use the app as well (Geber & Friemel, 2021).

Limitations

The present study significantly contributes to the current state of research on contact-tracing technology acceptance. However, there are some limitations that need to be considered. First, and most importantly, the focus of our empirical setting on a specific tracing technology in a single country limits the generalization of our findings. Hence, there is a need to investigate whether the influences found in this study can be replicated in other countries and regarding other tracing technologies, such as the tracing tokens that have been introduced in Singapore to complement the tracing app. The comparison of countries and technologies will require the consideration of a multitude of dimensions, such as legal regulations, technological features, and culture.

Second, because of the online mode of the survey, the study's sample should not be considered as representative for the population. This has become apparent in the relatively high percentage of app users in our sample one week after the release of the app in Switzerland. Our data suggested that adopters make up 54% of the population. Other online surveys conducted in Switzerland reported similarly high adoption rates of about 47% (Wyl et al., 2020) and 46% (Brüesch, Fischer, & Lang, 2020). These numbers are likely an overestimation of app adoption in the general population, due to the above-average affinity of online-panel participants for such technologies. However, as the study's primary aim was to learn about the correlations between app-related perceptions and app adoption and not about the rate of app adoption, this limitation does not concern the study's main aim.

Third, in terms of our measures, the internal consistency of some dimensions was found to be at the lower end of acceptable reliability (i.e., perceived ease of use, susceptibility to COVID-19, injunctive norm population). It is notable that we found satisfying reliability values for these dimensions in a further confirmatory factor analysis for the overall sample that included those participants who had already installed the app at the first measurement. Besides the indication of a systematic difference between the persons who had installed the app and those who had not installed the app at the first point of data collection, the lower consistency suggests that even more granular subdimensions need to be distinguished to understand the influence of app-related perceptions on app adoption intention.

Fourth, our research design with two panel waves was an important step toward testing the causal direction of different influences in a technology-adoption process. However, this design did not allow the investigation of more complex dynamics, such as a crucial tipping point in the diffusion process. Furthermore, a third wave would allow a study of the causality of the effects of the app-related perceptions on adoption intention that have been measured at a single timepoint.

Conclusion

The present study unfolds the multidimensional nature of contact-tracing technologies: They are not only technologies; their use also needs to be considered as health protection and cooperative behaviors. Accordingly, our results demonstrate the vital importance of perceptions about the tracing app's usefulness, user friendliness, and data protectiveness, as well as the social support for such technologies in the decision process of people who are not early adopters. Notably, in the reasoning process of those people, social

norms played a multifaceted role, as they not only motivated app adoption directly but also served as indicators for the users for the technology's usefulness. This complexity should be kept in mind in future research on contact-tracing technologies, but also in the development and implementation of such technologies as public health measures about COVID-19 and other communicable diseases.

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