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Examining the cultural dimension of contact-tracing app adoption during the COVID-19 pandemic: a cross-country study in Singapore and Switzerland

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ABSTRACT
Contact-tracing applications (CTAs) have been introduced as part of the COVID-19 containment strategy worldwide. In most countries, however, their uptake has been too low to realize their full potential. This study contributes to the understanding of CTA adoption by investigating the influence of public perceptions on adoption and the role of media in forming these perceptions in Singapore and Switzerland. In a comparative approach, online surveys in both countries (Singapore: $N = 998$; Switzerland: $N = 1{,}022$) and multigroup structural equation modeling reveal national differences. First, attention to media was associated more strongly with app-related perceptions in Singapore than in Switzerland, with news media attention correlating positively with favorable perceptions in both countries (i.e., perceived usefulness of the CTA, perceived social norms of adoption) and social media attention correlating negatively with these perceptions in Singapore. Second, regarding the influence of these perceptions on CTA adoption, perceived usefulness was associated with CTA adoption in Switzerland but not in Singapore; conversely, perceived social norms were more important in Singapore than in Switzerland. These results suggest that the communicative formation of public perceptions and their behavioral relevance are contingent on media systems (authoritarian vs. democratic media system) and cultural values (collectivism vs. individualism), highlighting the theoretical value of a country-comparative approach and the practical need for a culturally sensitive implementation of health technologies.

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Contact-tracing apps; technology adoption; health protection; COVID-19; cross-culture; media system

Contact-tracing applications (CTAs) have been introduced as part of a broader COVID-19 containment strategy in several countries in 2020 (Kahn, 2020). One year after their introduction, 120 CTAs were available in more than 70 countries (Woodhams, 2021). The primary function of these smartphone-based apps is to complement the manual tracing of transmission chains and thereby help to control the spread of COVID-19 (Kolasa

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et al., 2021). Thus, CTAs were introduced with the hope of controlling the pandemic while allowing the economic, political, and social systems to recover.

However, the effectiveness of such technologies depends on widespread adoption by the general population (Grekousis & Liu, 2021). Despite calls in the media by health authorities to adopt CTAs and assurances that these technologies protect users' privacy, adoption rates have been too low in most countries for the CTAs to realize their full potential (Grekousis & Liu, 2021). In Singapore, one of the first countries to deploy a national CTA in March 2020, the download rate had remained static for months at about 40% by early December 2020 (Gardner, 2020). Switzerland launched its CTA in June 2020 and recorded three million downloads, representing an adoption rate of 43% in December 2020, the time of this study (Federal Statistical Office, 2020b).[1] This demonstrates the need for a comprehensive understanding of CTA adoption in distinct cultural contexts.

As CTAs have emerged only recently in response to the COVID-19 pandemic, the understanding of their adoption is limited. A scoping review of 25 studies indicates three research gaps (Villius Zetterholm et al., 2021). First, studies on CTA acceptance[2] were based on several theoretical models, including the technology acceptance model (TAM; Davis, 1989; see, e.g., Walrave et al., 2021), health belief model (HBM; Rosenstock et al., 1988; see, e.g., Walrave et al., 2020), and protection motivation theory (PMT; Rogers, 1975; see, e.g., Kaspar, 2020). However, only a few studies used an integrative approach and combined different CTA perceptions (e.g., Sharma et al., 2020b; Tomczyk et al., 2021). More importantly, none of them considered the role of media in forming public perceptions, even though research on media effects has demonstrated that communication can shape public perceptions towards various issues (e.g., Valkenburg et al., 2016). Second, these studies covered a range of countries, but only a few used a comparative approach (Altmann et al., 2020; Simko et al., 2020). Thus far, only one study has examined CTA adoption in countries with distinct cultural backgrounds, comparing Germany, the United States, and China (Kostka & Habich-Sobiegalla, 2020). Lastly, most studies examined the intention to install a (hypothetical) CTA, and there is minimal evidence from actual adoption (e.g., Abuhammad et al., 2020; Munzert et al., 2021; von Wyl et al., 2021). Given the evidence concerning the gap between behavioral intention and actual behavior (Sheeran & Webb, 2016), this is a crucial shortcoming.

The present study addresses these gaps by investigating the influence of public perceptions on CTA adoption and the role of media in perception formation in Singapore and Switzerland based on online surveys in both countries in early December 2020 (Singapore: $N = 998$; Switzerland: $N = 1{,}022$). It contributes to the current research in three regards. First, the study's framework integrates perceptions from the TAM (i.e., perceived usefulness and ease of use; Davis, 1989) and health protection research (i.e., perceived threat; Rogers, 1975; Rosenstock et al., 1988) and considers the role of media attention in shaping public perceptions of CTAs. This allows for assessing the relative importance of different CTA perceptions and understanding their communicative formation. Second, the study uses a cross-country approach and compares CTA adoption and its factors in Singapore and Switzerland. This country comparison promises to be insightful beyond both cases, as they can be regarded as exemplars of Eastern (i.e., Singapore) and Western (i.e., Switzerland) countries. Thus, the comparative approach enables us to assess the extent to which our framework is system- and culture-sensitive or, rather, generalizable and applicable to other countries and cultures (Esser & Vliegenthart, 2017). Third, the findings present

reports of actual CTA adoption, not behavioral intention, and thereby overcome the intention–behavior gap in current CTA acceptance research (Villius Zetterholm et al., 2021).

An integrative framework of CTA adoption

The study's framework acknowledges that CTAs are both digital technologies and health protection measures and synergizes evidence in the traditions of the TAM (Davis, 1989) and health protection research (HBM, Rosenstock et al., 1988; PMT, Rogers, 1975). Further, it integrates the important role of media attention in perception formation. Figure 1 presents the framework and hypotheses, which are developed in the following sections.

Media attention

Attention to news media

During a health crisis, such as the COVID-19 pandemic, public perceptions of the disease and protective measures depend heavily on communication (Vaughan & Tinker, 2009). News media, such as newspapers and television, have been the dominant sources of health information during the COVID-19 pandemic in Western (Liu et al., 2020) and Eastern countries (Tang & Zou, 2021). Consequently, they are vital shapers of the public's health-related perceptions. Initial research in the COVID-19 context indicates that attention to news media affects perceptions of the threat of the virus and public health measures (Friemel & Geber, 2021; Jiang et al., 2022; Nazione et al., 2021). We, therefore, assume that attention to news media forms public perceptions of CTAs and hypothesize as follows:

H1: Attention to news media affects app-related perceptions.

Attention to social media

Given the increasing number of information sources, people do not need to on traditional news media to obtain relevant health information during a public health crisis.

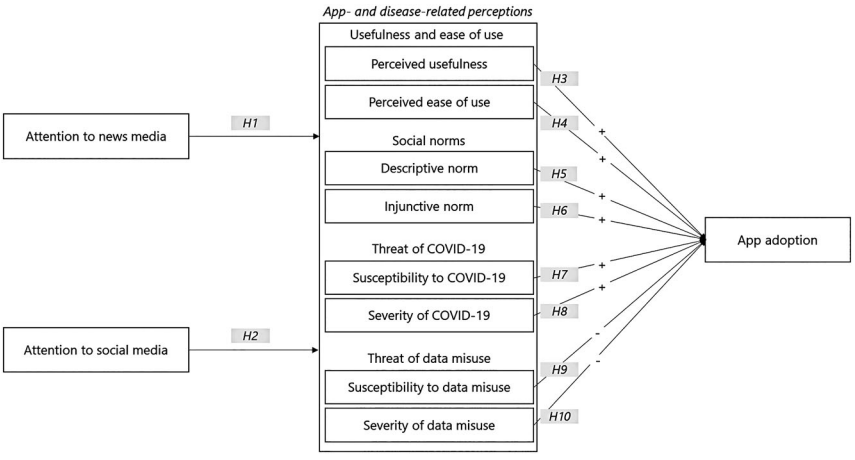

Figure 1. Hypothesized framework on contact-tracing app adoption.

Studies in the COVID-19 context conducted in China (Li & Liu, 2020) and the United States (Nazione et al., 2021) identified social media as an important means for people to stay informed about the health crisis. These studies also revealed that attention to social media affected health-related perceptions (Li & Liu, 2020; Nazione et al., 2021). Accordingly, we hypothesize as follows:

H2: Attention to social media affects app-related perceptions.

Technology acceptance

Perceived usefulness and perceived ease of use

To identify adoption-relevant perceptions, we refer to the TAM (Davis, 1989). The TAM aims to explain users' adoption of technological innovation and is mainly organized around two constructs: perceived usefulness and perceived ease of use. When applied to contact-tracing technology, *perceived usefulness* refers to the perception of how useful the CTA is in helping the user identify a potential infection, and *perceived ease of use* refers to the degree to which a person believes that using the CTA is easy and effortless in everyday life (Davis, 1989).

In terms of CTA acceptance, studies found perceived usefulness (Geber & Friemel, 2022; Tomczyk et al., 2021) and conceptually related constructs, such as performance expectancy (Walrave et al., 2021) or expected outcomes (Sharma et al., 2020b), to be positively related to CTA adoption intention. This has been consistent across multiple countries (Kostka & Habich-Sobiegalla, 2020). The findings regarding perceived ease of use as a predictor of CTA adoption are less clear. While Tomczyk et al. (2021) did not identify a correlation between perceived ease of use and CTA adoption intention in Germany, studies conducted in Belgium found perceived ease of use to increase adoption intention (reported as facilitating conditions in Walrave et al., 2020, or self-efficacy in Walrave et al., 2020). Considering the research on CTA acceptance and general findings in line with the TAM (King & He, 2006; Schepers & Wetzels, 2007), we assume that both perceived usefulness and perceived ease of use postitively affect the intention to install a CTA:

H3/H4: Perceived usefulness (*H3*) and perceived ease of use (*H4*) of the CTA positively affect CTA adoption.

Social norms

Social influences were included later in technology acceptance research (Venkatesh & Davis, 2000) in the form of subjective norms. To understand social norms more comprehensively, we differentiate between perceived descriptive and injunctive norms (Cialdini et al., 1990). In the case of CTA adoption, *descriptive norms* refer to the perceived prevalence of CTA adoption in the population, whereas *injunctive norms* show parallels to subjective norms and pertain to the perceived social approval of CTA adoption (Cialdini et al., 1990).

Studies identified social influences in the context of CTA adoption (Sharma et al., 2020b; Tomczyk et al., 2021). Specifically, research shows that perceptions about population's descriptive norm were associated with app adoption in Switzerland among

people who initially hesitated to install and use the app (Geber & Friemel, 2022) and that both perceived descriptive and injunctive norms were correlated with CTA adoption in Singapore (Lee et al., 2021). Thus, based on the cumulative empirical evidence of normative effects on behavioral intention in technology acceptance research (Schepers & Wetzels, 2007) and health behavior research (Sheeran et al., 2016), as well as the state of research on CTA acceptance (Villius Zetterholm et al., 2021), we hypothesize as follows:

H5/H6: Descriptive norms (*H5*) and injunctive norms (*H6*) of CTA adoption in the population positively affect CTA adoption.

Health protection motivation

Threat of COVID-19

As CTAs are not only new technologies but also public health measures, their adoption must be considered a health protection behavior. The HBM (Rosenstock et al., 1988) and PMT (Rogers, 1975) refer to perceived threat as an important predictor of health protection behavior (Prentice-Dunn & Rogers, 1986), differentiated into perceived susceptibility (referred to as vulnerability in the PMT) and severity. We define *perceived susceptibility* as the subjective perception of the risk of being infected with COVID-19 and *perceived severity* as the magnitude of a negative health outcome of a COVID-19 infection (Kowalski & Black, 2021).

Research on the relationship between a perceived health threat and CTA acceptance 'shows some mixed results' (Villius Zetterholm et al., 2021, p. 9). While studies found that fear of COVID-19 was correlated with the intention to use the CTA across different cultural contexts (Kostka & Habich-Sobiegalla, 2020), in a study using a German sample, perceived susceptibility and severity were not related to CTA adoption intention (Kaspar, 2020). However, given the strong theoretical and empirical findings on threat perception as a motivation for displaying health protection behavior, we assume that both susceptibility and severity perceptions influence CTA adoption intention:

H7/H8: Susceptibility to (*H7*) and severity of COVID-19 (*H8*) positively affect CTA adoption.

Threat of data misuse

Privacy was a central feature of debates around CTAs (Kolasa et al., 2021), which is why we include perceived threat of data misuse in our model. Following the definition of perceived threat in the HBM (Rosenstock et al., 1988) and PMT (Rogers, 1975), our framework differentiates between perceived susceptibility to and perceived severity of data misuse. While Geber and Friemel (2022) found that only perceived severity of data misuse was correlated with reduced CTA adoption intention in Switzerland, Kaspar (2020) identified both susceptibility to and severity of data misuse as significant predictors in Germany. Given the cumulative evidence of the negative effects of the perceived threat of data misuse in CTA acceptance research (Villius Zetterholm et al., 2021), we posit the following:

H9/H10: Susceptibility to (*H9*) and severity of data misuse (*H10*) due to the CTA negatively affect CTA adoption.

Cross-cultural contexts: Singapore and Switzerland

We apply our theoretical framework to study CTA adoption in Singapore and Switzerland. We choose these two countries because knowledge of factors of CTA adoption in both countries is scarce (cf. Saw et al., 2021; von Wyl et al., 2021) and – more importantly – because comparing Singapore, an Eastern country, and Switzerland, a Western country, allows for investigating the role of cultural differences in the associations between media attention, public perceptions, and CTA adoption. Singapore and Switzerland are especially suitable cases for such a cross-cultural approach because they have comparable technological infrastructures and CTAs while differing in their media systems and cultural values.

Similarities in technological infrastructures and CTAs

Singapore and Switzerland have well-established technological infrastructures: over 80% of the population in both countries owns a smartphone (Statista, 2020a, 2020b). Thus, the introduction of CTAs in response to the COVID-19 pandemic has been theoretically promising, making the low CTA acceptance rate in both countries worth studying. Further, the countries' CTAs are comparable: Singapore's TraceTogether app and Switzerland's SwissCovid app employ Bluetooth technology to allow smartphones to communicate with each other anonymously (Kolasa et al., 2021). They follow the principle of 'privacy by design' (Cavoukian, 2010), meaning that privacy and security protections are built into the technology to ensure data security (rather than relying solely on responsible use).

Differences in media systems and cultural values

Singapore and Switzerland are also exemplars of Eastern and Western countries, manifesting differences in their media systems and cultural values. The Swiss media system is classified as a democratic corporatist model (Hallin & Mancini, 2006); the Singaporean media system, in contrast, is rather authoritarian (Wong, 2008). Specifically, the Singaporean mass media is wholly state owned and information flow is tightly controlled and regulated by the government (George, 2007). In less democratic environments, social media might provide alternative spaces for a more critical public debate (Goh & Pang, 2016), suggesting that social media may have different effects than mass media in such countries.

Besides system-related variation, some notable differences between Eastern and Western countries concern the individualism–collectivism dimension (Henrich et al., 2010). According to the work of Hofstede and colleagues (Hofstede Insights, 2020), Singapore can be regarded as a collectivist society prioritizing the interests of the community (individualism score: 20) and Switzerland as a rather individualistic society placing value on individuals' independence (individualism score: 68). The collectivism–individualism dimension is commonly applied in technology acceptance research (Leidner & Kayworth, 2006) and has been found to play a crucial role in technology adoption (e.g., Sharma et al., 2020a). As regards CTA adoption, there is initial evidence that public perceptions and their associations with CTA acceptance depend on the individualism–collectivism dimension (Kostka & Habich-Sobiegalla, 2020; Sharma et al., 2020b).

Consequently, Villius Zetterholm et al. (2021) concluded in their literature review that variations in the relative importance of factors of CTA adoption may be explained by differences in the individualism–collectivism dimension.

In conclusion, differences between Singapore's and Switzerland's media systems and cultural values present different conditions for (a) the impact of media attention on app-related perceptions (*H1* and *H2*) and (b) the effects of such perceptions on CTA adoption (*H3–H10*). We, thus, pose the following research question:

> *RQ1:* Are there differences between Singapore and Switzerland in the influences of attention to mass media and social media on app-related perceptions (*RQ1a*) and the influences of these perceptions on app adoption (*RQ1b*)?

Methods

We conducted online surveys in both countries. Prior to data collection, the procedure and questionnaire were approved by the Institutional Review Board of the Nanyang Technology University, Singapore, IRB-2020-11-008. As part of the ethical requirements, participants were informed about the study's procedure, their right to refuse or withdraw from the study, and the anonymity of their data and were asked to provide consent before starting the survey.

Data collection

The data collection was realized in collaboration with research institutes in both countries: Qualtrics in Singapore and Intervista in Switzerland. The research institutes administered the online questionnaires via their survey software. Soft launches, where the link was sent to a limited sample (about 50 participants in each sample), were used to rule out technological and procedural issues.

Data collection started on December 1, 2020, and was completed on December 15 in Switzerland and December 21 in Singapore. Quotas were set for age, gender, and education to represent the different sociodemographic groups in both populations. In Switzerland, data collection targeted the German-speaking part (i.e., excluding the Swiss-French and Swiss-Italian regions), which is Switzerland's largest region (63%; Federal Statistical Office, 2020a). Members of both research panels received an email invitation to participate in a survey on information and communication behavior related to COVID-19 and were compensated within the research institutes' rewards systems, including gift cards, charitable donations, and vouchers. The average completion time was 19 min in both samples. The data screening procedure included checks of the respondents' processing duration and the analysis of a bogus item (i.e., a test item to assess whether respondents were providing ostensibly substantive answers), resulting in the deletion of 37 Singaporean cases and 25 Swiss cases.

Sample

The final sample sizes were 998 for Singapore and 1,022 for Switzerland. In the Singaporean sample, 49% of respondents were female, and their ages ranged from 21 to 84 years

($M = 39.21$, $SD = 12.74$). The Swiss sample was 51% female, and the ages ranged from 18 to 85 years ($M = 47.6$, $SD = 17.5$).[3] In the Singaporean sample, 42% of respondents held a university degree; in the Swiss sample, 31% of respondents had a university degree.

Measures

Measures were assessed using an English questionnaire in Singapore and a German questionnaire in Switzerland. To ensure that the English and German questions/items were identical in meaning, translations were checked back and forth between the authors, one of whom is a native English speaker and one a native German speaker.

Media attention

Respondents were asked whether they generally read newspapers (either in print or online), watch news telecasts (either on television or online), or listen to radio news (either on the radio or online). If they answered 'yes', they were asked separately for each medium how much attention they paid to messages about the CTA on a 5-point scale ranging from 1 = *no attention at all* to 5 = *a lot of attention* (negative answers to the general media use question were recoded as 1 = *no attention at all*). For the items' wordings, means, and standard deviations, see Table 1. Similarly, attention to social media was assessed with a general question about social media use (e.g., Facebook, Twitter, Instagram) and a follow-up question about attention to messages about the CTA on social media (Singapore: $M = 3.32$, $SD = 1.34$; Switzerland: $M = 1.69$, $SD = 1.10$). Comparable measures were used in previous studies on the effects of media attention (e.g., Ho et al., 2020).

App-related perceptions

Except for perceived descriptive norms, all app-related perceptions were assessed by three items on a 5-point scale ranging from 1 = *strongly disagree* to 5 = *strongly agree* (see Table 1 for the wordings of these items). Items concerning perceived usefulness and ease of use were worded similarly to measurements applied in technology acceptance research (e.g., Davis, 1989). Items regarding 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). Perceived descriptive norms were measured as perceived prevalence of CTA adoption by asking respondents to estimate the percentage of the population currently using the CTA (Singapore: $M = 66.0$, $SD = 20.5$; Switzerland: $M = 40.1$, $SD = 18.8$). Perceived injunctive norms were assessed by perceived social approval statements. The German items had been applied in a prior study on CTA adoption (Geber & Friemel, 2022). Table 1 reports the means and standard deviations for all multi-item constructs.

App adoption

We asked respondents to indicate whether they have installed and currently use the CTA by providing the following answer options: 1 = *yes, and I use it*; 2 = *yes, but I have deactivated it*; 3 = *no, because I haven't installed it (yet)*; 4 = *no, because I've uninstalled it already*; and 5 = *no, because I do not have a smartphone*. We used their answers to this question to compute a binary variable of app adoption, defined as having the app installed and using it (1) or not (0, combining all other options). App adoption was

Table 1. Measures of latent variables.

Latent variables and items	SG		CH	
	α/Std. loading	*M* (*SD*)	*α*/Std. loading	*M* (*SD*)
Attention to news media	*α* = .66	3.38 (1.14)	*α* = .81	2.40 (1.12)
Attention to messages about the tracing app in the newspapers	.68	3.55 (1.21)	.78	2.51 (1.30)
Attention to messages about the tracing app in news telecasts	.69	3.67 (1.39)	.87	2.51 (1.34)
Attention to messages about the tracing app in radio news	.57	2.94 (1.79)	.65	2.17 (1.29)
Perceived usefulness	*α* = .88	3.85 (0.87)	*α* = .89	3.21 (1.13)
If I use the tracing app, it helps me to recognize a possible infection at an early stage.	.83	3.89 (0.98)	.85	3.33 (1.30)
When I use the tracing app, I am reliably informed of the possibility of infection.	.84	3.84 (0.95)	.88	3.21 (1.21)
The tracing app reliably warns me if I was exposed to a risk of infection.	.85	3.83 (0.97)	.85	3.08 (1.21)
Perceived ease of use	*α* = .86	3.90 (0.90)	*α* = .86	4.00 (1.19)
It's very easy for me to install the tracing app.	.73	4.06 (0.96)	.77	4.14 (1.29)
I am confident that I can use the tracing app without any problems.	.87	3.84 (1.04)	.82	4.07 (1.31)
I can use the tracing app in everyday life without any problems.	.87	3.80 (1.06)	.86	3.80 (1.43)
Injunctive norm population	*α* = .86	3.31 (0.84)	*α* = .90	2.98 (0.81)
The Singaporean/Swiss population thinks it is important to use the tracing app.	.82	3.36 (0.95)	.86	2.98 (0.90)
The Singaporean/Swiss population is in favor of using the tracing app.	.82	3.27 (0.95)	.88	3.04 (0.87)
The Singaporean/Swiss population is generally positive about the tracing app.	.83	3.29 (0.96)	.85	2.93 (0.89)
Susceptibility to COVID-19	*α* = .86	3.09 (1.00)	*α* = .84	2.99 (0.96)
The risk is high that I will get Covid-19.	.87	3.05 (1.16)	.85	2.79 (1.08)
It is likely that I will get Covid-19.	.81	2.88 (1.13)	.80	2.77 (1.05)
There is a risk that I will get infected with Covid-19.	.78	3.32 (1.11)	.74	3.42 (1.17)
Severity of COVID-19	*α* = .83	4.03 (0.85)	*α* = .91	3.14 (1.14)
If I get Covid-19, it has serious consequences for my health.	.87	4.07 (0.96)	.88	3.14 (1.22)
Illness from Covid-19 would have far-reaching negative consequences for me.	.72	3.89 (1.03)	.88	3.02 (1.23)
A Covid-19 disease would be bad for me.	.80	4.14 (0.95)	.88	3.24 (1.25)
Susceptibility to data misuse	*α* = .88	3.56 (1.00)	*α* = .88	2.56 (1.19)
There is a high risk that my data can be misused if I use the tracing app.	.88	3.53 (1.13)	.88	2.44 (1.31)
It is likely that the tracing app collects too much data about me.	.84	3.58 (1.10)	.84	2.71 (1.38)
It is likely that the tracing app makes private information accessible to others.	.79	3.58 (1.11)	.79	2.54 (1.30)
Severity of data misuse	*α* = .81	3.92 (0.89)	*α* = .86	2.88 (1.19)
If the data recorded by the app were misused, it would have serious consequences for me and my privacy.	.77	4.09 (1.01)	.84	2.83 (1.35)
If the tracing app collected too much data about me, it would be bad for me.	.76	3.76 (1.10)	.80	2.92 (1.37)
If private information were made available to others via the tracing app, it would have negative consequences for me.	.76	3.90 (1.05)	.81	2.88 (1.31)

Note. $N_{SG} = 998$, $N_{CH} = 1{,}022$; confirmatory factor analysis with robust maximum likelihood estimator; $\chi^2(448) = 902.44$, $p < .001$; $\chi^2/df = 2.01$; CFI = 0.979; RMSEA = .032, 90% CI [.029, .034]; SRMR = .033; SG = Singapore; CH = Switzerland; *α* = Cronbach's alpha, std. loadings = standardized factor loadings.

comparable across countries – 57% of Singaporean respondents and 56% of Swiss respondents.

Data analysis

We used multigroup structural equation modeling (SEM) to examine the relations between media attention, app-related perceptions, and app adoption in Singapore and Switzerland (*H1* to *H10*) and differences in these relations between the countries

(*RQ1*/*RQ2*). As the primary approach of this study was not exploratory but confirmatory, we chose covariance-based SEM (CB-SEM) over variance-based SEM (PLS-SEM; Hair et al., 2017). All analyses were conducted in R with the lavaan package (Rosseel, 2012).

We first performed a confirmatory factor analysis (CFA) to test our multi-item measures for attention to mass media and perceptions. A set of fit indices (Hu & Bentler, 1999) revealed a good fit for the CFA in both samples (model SG_{CFA} and CH_{CFA}, Table 2). The measures in both samples also showed good internal consistency (Table 1). Further, we tested the measurement model in both countries simultaneously using the multigroup function (model $MULTI_{CFA,}$ Table 2), which indicated that the measurement properties of the model fit both samples. We tested for factor loading invariance – a precondition to compare path coefficients between groups – by constraining loadings to be equal among both groups (model $MULTI\text{-}CONST_{CFA}$) and comparing this constrained model to the original multigroup model ($MULTI_{CFA}$). We found weak invariance, as the difference between the two models in the comparative fit index (CFI) was less than |0.01| and in the root mean square error of approximation (RMSEA) was less than .015 (Chen, 2007).

Second, we tested the relations as hypothesized in *H1* to *H10* in an SEM. The model included age, gender, and education as control variables[4] and covariances between both media attention variables and between perceptions with the same theoretical background (i.e., perceived usefulness and ease of use; descriptive and injunctive norms; susceptibility and severity; see Figure 2). For all variables, the variance inflation factor (VIF) was less than 2.9 in the Singaporean sample and less than 3.3 in the Swiss sample, indicating no multicollinearity issues. As the outcome was a binary variable (i.e., CTA adoption), we used robust maximum likelihood estimation (Bandalos, 2014).

The multigroup model showed a good fit to the data ($MULTI_{SEM}$, Table 2). We tested for differences in paths between the Singaporean and Swiss samples by comparing this (unconstrained) multigroup model ($MULTI_{SEM}$) with a constrained model in which the regression coefficients were held equal across the two countries ($MULTI\text{-}CONST_{SEM}$). The difference in goodness of fit between the models was significant ($\chi^2 = 466.8$, $p < .001$), implying significant differences in some paths of the Singaporean and Swiss models. Thus, to answer *RQ1*, we identified the paths causing the difference by constraining the regression paths (one at a time) and testing for differences in goodness of fit (Table 3).

Table 2. Measurement and structural equation models.

Model	χ^2	*df*	*p*	χ^2/df	CFI	RMSEA	SRMR
Measurement models							
SG_{CFA}	371.30	224	<.001	1.66	.985	.026	.032
CH_{CFA}	538.06	224	<.001	2.40	.974	.037	.036
$MULTI_{CFA}$	902.44	448	<.001	2.01	.979	.032	.033
$MULTI\text{-}CONST_{CFA}$	953.90	464	<.001	2.10	.977	.032	.034
Structural models							
SG_{SEM}	752.79	346	<.001	2.18	.963	.034	.054
CH_{SEM}	1083.29	346	<.001	3.13	.949	.046	.068
$MULTI_{SEM}$	1828.04	692	<.001	2.64	.955	.040	.059
$MULTI\text{-}CONST_{SEM}$	2255.35	749	<.001	3.01	.940	.045	.081

Note. $N_{SG} = 998$, $N_{CH} = 1{,}022$; CFA = confirmatory factor analysis; SEM = structural equation model; CFA and SEM with robust maximum likelihood estimator; SG = Singapore; CH = Switzerland; MULTI = multigroup model; MULTI-CONST = constraint model (factor loadings (CFA)/regression coefficients (SEM) are constrained to be equal across groups).

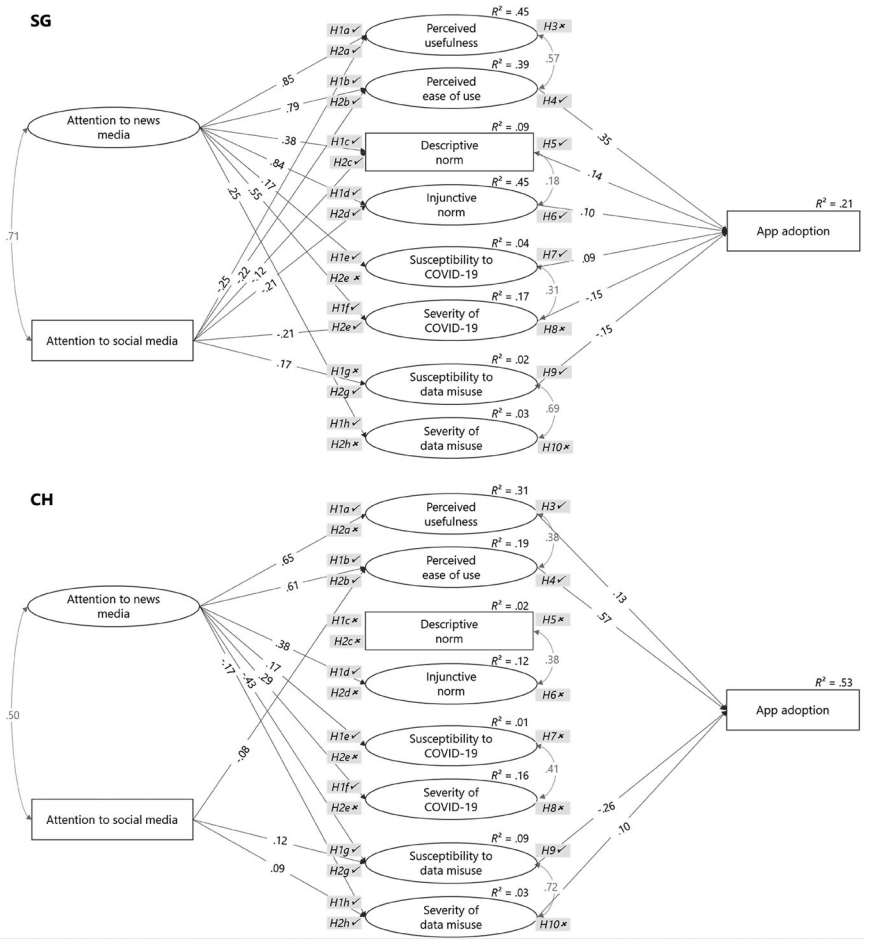

Figure 2. Structural equation model for contact-tracing app adoption in Singapore and Switzerland. *Note*. $N_{SG} = 998$, $N_{CH} = 1{,}022$; structural equation model with robust maximum likelihood estimator; $\chi^2(692) = 1826.42$, $p < .001$; $\chi^2/df = 2.63$; CFI = 0.955; RMSEA = .040, 90% CI [.038, .042]; SRMR = .059; ellipses represent latent measures; the measurement model is documented in Table 1; age, gender, and education were included as control variables but are not displayed for clarity; only significant paths are displayed (at the 5-percent level, $p \leq .05$); scores report standardized coefficients; $R^2 = r$ square, only includes the variance explained by the variables of theoretical interest (i.e., excludes variance explained by control variables), SG = Singapore; CH = Switzerland.

Results

The model explained about 20% of the variance of CTA adoption in Singapore and 50% in Switzerland. In what follows, we present the hypothesis tests reflecting the paths (*H1–H10*, Figure 2) and the test of differences between the two countries as inquired in *RQ1* (Table 3).

Attention to news media was associated with increased favorable perceptions, such as perceived usefulness and ease of use of the CTA and perceived social norms toward CTA adoption in the population, corroborating *H1*. Concerning *RQ1*, we found these

Table 3. Test for differences in paths between Singapore and Switzerland.

Path		$\Delta\chi^2$	*p*
	Attention to news media		
H1a	→ Perceived usefulness	2.76	.097
H1b	→ Perceived ease of use	1.51	.219
H1c	→ Descriptive norm	21.90	< .001
H1d	→ Injunctive norm	33.97	< .001
H1e	→ Susceptibility to COVID-19	0.66	.418
H1f	→ Severity of COVID-19	10.94	< .001
H1g	→ Susceptibility to data misuse	93.89	<.001
H1h	→ Severity of data misuse	119.71	<.001
	Attention to social media		
H2a	→ Perceived usefulness	2.87	.090
H2b	→ Perceived ease of use	0.56	.454
H2c	→ Descriptive norm	6.08	.014
H2d	→ Injunctive norm	4.09	.043
H2e	→ Susceptibility to COVID-19	0.26	.613
H2f	→ Severity of COVID-19	12.75	<.001
H2g	→ Susceptibility to data misuse	0.01	.915
H2h	→ Severity of data misuse	8.11	.004
	→ App adoption		
H3	→ Perceived usefulness	2.55	.110
H4	→ Perceived ease of use	0.49	.486
H5	→ Descriptive norm	7.97	.005
H6	→ Injunctive norm	8.04	.005
H7	→ Susceptibility to COVID-19	4.65	.031
H8	→ Severity of COVID-19	25.95	<.001
H9	→ Susceptibility to data misuse	1.65	.200
H10	→ Severity of data misuse	0.84	.359

Note. $N_{SG} = 998$, $N_{CH} = 1{,}022$.

correlations in both countries, but most of them were significantly stronger in Singapore than in Switzerland (Table 3). Regarding *H2*, in Singapore, attention to social media was associated with a reduction in several favorable perceptions (perceived usefulness, ease of use, descriptive norms, injunctive norms) and with increased perceived susceptibility to data misuse. In contrast, in Switzerland, we found only three weak correlations of attention to social media with app-related perceptions (perceived ease of use, susceptibility to and severity of data misuse). Thus, *H2* obtained more support in Singapore than in Switzerland. Most of the negative correlations between social media and app-related perceptions were stronger in Singapore than in Switzerland (Table 3).

Turning to the influences of these perceptions on CTA adoption, perceived usefulness was not associated with adoption in the Singaporean sample but it was in the Swiss sample, supporting *H3* only for the latter, but the difference in the path of perceived usefulness on CTA adoption was not significant (Table 3). Perceived ease of use was adoption-relevant to the same extent in both countries, corroborating *H4* in both samples. The hypotheses on social norms, *H5* (descriptive norms) and *H6* (injunctive norms), found support in Singapore but not in Switzerland. Supporting this result, normative influences were significantly stronger in Singapore than in Switzerland (Table 3). The hypothesis reflecting the path between susceptibility to COVID-19 and CTA adoption, *H7*, was supported in Singapore but not in Switzerland, and the correlation was significantly different in both countries (Table 3). In Singapore, severity of COVID-19 was negatively correlated with CTA adoption, contrary to *H8* and in contrast to Switzerland, where no significant correlation was found, causing the rejection of *H8* in both countries.

Susceptibility to data misuse was negatively correlated with CTA adoption to the same extent in Singapore and Switzerland, supporting *H9* in both countries. Severity of data misuse was not associated with CTA adoption in Singapore and was weakly positively correlated with CTA adoption in Switzerland, prompting the rejection of *H10* in both countries.

Discussion

The study provides evidence of communicative influences on app-related perceptions and influences of these perceptions on CTA adoption. It however also indicates that the role of media and certain perceptions of CTAs are culture-contingent. Next, we discuss the results, focusing on the most important differences between Singapore and Switzerland.

Differences in the role of media

Generally, the results reveal that the correlations between news media and favorable app-related perceptions were stronger in Singapore than in Switzerland. This is particularly true in the case of normative perceptions. In Singapore, nearly half the variance in injunctive norm perception was explained by attention to mass media. This result corroborates the CTA's framing as a community effort in Singapore, as is apparent in the app's name, TraceTogether, and the campaign's slogan, 'Protect your community' (Singapore Government, 2021). This framing refers to the responsibility of the whole population and to the injunctive norm that every community member is expected to use the app. As the main function of mass media in Singapore is to serve national interests (Lee, 2000), it is unsurprising that the mass media would echo the campaign's message, as in previous pandemics, such as in the H1N1 flu pandemic (Ho, 2012). Another important difference is that attention to news media was associated with reduced perceived severity of data misuse in Switzerland and with heightened perceived severity of data misuse in Singapore. Media reporting on the privacy of the Swiss CTA and its data storage system was relatively supportive (Zimmermann et al., 2021), which might have reduced the perceived threat regarding data misuse in the Swiss population. By contrast, in Singapore, privacy concerns about the TraceTogether app sparked heated debates in the mass media. This was, in part, triggered by revelations that law enforcers were empowered to obtain TraceTogether data for criminal investigations, despite the government's previous assurances to citizens that the app was not meant for such purposes (Chia, 2021).

Regarding the impact of social media, we found substantial differences between Singapore and Switzerland. The correlations of social media with reduced favorable app-related perceptions (e.g., social norms) and increased data misuse perceptions were significantly stronger in Singapore than in Switzerland, suggesting that social media played a rather destructive role in the public debate about the CTA in Singapore. Studies on the 2015 Singapore general election (Soon & Samsudin, 2016) and protests against the government's immigration policy (Goh & Pang, 2016) found that social media was used to discuss politics critically and to organize protests. Our study corroborates these findings and the idea of social media as an alternative place for public debate (Goh & Pang, 2016),

as reflected in the result that the negative effects of social media attention contradict the positive effects of mass media attention.

Differences in the role of app-related perceptions

There were also significant variations in the behavioral relevance of certain perceptions. Most notably, perceived usefulness was a correlate of CTA adoption in Switzerland but not in Singapore, and conversely, perceived social norms played a significantly more important role in CTA adoption in Singapore than in Switzerland. This can be explained by differences in cultural orientations that have already been shown to make a difference in the tradition of the TAM (Davis, 1989). That CTA adoption is less a question of the app's effectiveness and more a question of social norms reflects the collectivistic culture, where high importance is placed on belonging to the community and, thus, on an orientation toward others' behaviors and opinions (Muthukrishna & Schaller, 2020). On the other hand, it is not surprising that in Switzerland, a more individualistic country, perceptions of the effectiveness of the CTA would be behaviorally relevant (McCoy et al., 2007; Straub et al., 1997).

The last note on differences concerns the explanatory power of the framework in Switzerland and Singapore. While CTA adoption was explained by more than half the variance in Switzerland, only about a fifth was explained in Singapore. Two developments in Singapore must be considered in this regard. First, in tandem with the CTA, the Singaporean government made tokens available for collection from September 14, 2020, mainly for older adults who may not own a smartphone (Singapore Government, 2021). Thus, the TraceTogether program has allowed Singaporeans to choose between the app and the token. Second, since the end of December 2020, the TraceTogether app or token has been required to check in at venues, including restaurants, workplaces, schools, and shopping malls. Thus, though the use of TraceTogether is formally not mandatory, it has become a requirement for visiting public places in Singapore. This explains why CTA adoption was less a question of individual perception and more one of necessity.

Theoretical implications

The results have three theoretical implications. First, they show that our framework's communication-driven perspective is highly insightful. Attention to mass media and social media explained more than 20% and up to 45% of the variance in certain perceptions (i.e., perceived usefulness, ease of use, injunctive norms). This finding aligns with media effects research (e.g., Valkenburg et al., 2016) and contributes to current technology acceptance and health protection research, which lacks a theoretical understanding of how public perceptions are developed. This study highlights the significance of communication in this regard and suggests that future research should go beyond perceptions as predictors of individual behavior and acknowledge the role of communication in perception formation.

Second, the integration of public perceptions from the TAM (Davis, 1989) and health protection research (Rogers, 1975; Rosenstock et al., 1988) supports that 'technology acceptance needs to be understood from a 'holistic perspective' (Villius Zetterholm et al., 2021, p. 12). Although the TAM's predictors (i.e., perceived usefulness, ease of

use) were the most important correlates of CTA adoption, the integration of the threat dimension (related to the pandemic and data misuse) added to the explanation of CTA adoption. Further, the findings demonstrate that the differentiation of descriptive and injunctive dimensions should be considered in further technology acceptance research, which has thus far considered normative influences only rarely and in a rather abstract way (i.e., as subjective norms, referring to one's perception that important others expect one to exhibit certain behavior; Schepers & Wetzels, 2007).

Third, our results underline the need to consider the cultural context in technology acceptance and health protection research. Differences in media systems and cultural values may affect the perception formation process and the influence of perceptions on health technology adoption. Specifically, we found that in a more strictly regulated media system, such as in Singapore, social media seems to play a more crucial role in perception formation and social norms are more behaviorally relevant in collectivistic cultures. However, the results have limited generalizability. There is a need for research comparing more than two countries and including countries that vary in other dimensions of culture and media systems to systematically examine the roles of these dimensions in perception formation and CTA adoption.

Practical implications

The framework's communication-driven perspective highlights vital starting points for communication strategies that should accompany CTA implementation and the introduction of health technologies more generally. Concretely, our results suggest that communication should focus on the technologies' ease of use. Such messages seem promising globally, as the perceived ease of use was an important predictor of CTA adoption and was also strongly formed through communication in Singapore and Switzerland. Further, messages about the app's privacy-protecting design might counteract negative perceptions of potential data misuse that hindered CTA adoption in both countries. Thus, when health authorities plan to implement health technologies, they should clearly communicate the technologies' user friendliness and data protectiveness (Zimmermann et al., 2021).

Beyond these commonalities, the study suggests that communication strategies must reflect cultural differences to be effective. Specifically, in Singapore, social norms messages might promote CTA uptake. Social norms are not only predictors of CTA adoption; injunctive norms specifically appear to be strongly shaped by communication. By contrast, in Switzerland, communication should focus on the effectiveness of tracing technology. Thus, health authorities and technology developers must communicate the objectives and contribution of the technology (Zimmermann et al., 2021).

Limitations

This study had limitations that can provide directions for future research. First, as the primary aim was to examine cultural differences between Singapore and Switzerland in covariances between media attention, public perceptions, and CTA adoption, two national cross-sectional surveys were analyzed. The cross-sectional design, however, did not allow us to conduct empirical tests on underlying causal assumptions.

Thus, future studies should adopt longitudinal designs to control for rivaling explanations, such as selective media attention based on pre-existing perceptions or behaviors. Furthermore, although the study's timing allowed us to measure the intention to download and use the CTA and ask respondents about their actual CTA adoption, we still relied on their self-reports. Mobile tracking data could be a more reliable measure of CTA usage (e.g., Munzert et al., 2021). Comparably, content analysis data on media reporting and social media communication would help to substantiate the interpretations about media effects. Ideally, future studies should combine longitudinal data collection of media reporting, public perceptions, and CTA usage with a cross-national approach. Second, the COVID-19 pandemic unfolded differently in Singapore and Switzerland, restricting the countries' comparability. While Singapore counted less than 10 new cases per day at the time of data collection (i.e., beginning of December 2020), Switzerland was facing a second wave with increasing infections (Johns Hopkins University, 2020). This limitation suggests the need for more continuous monitoring of variables of interest during dynamic events, such as a pandemic. Third, online surveys represent Internet users – a sample that is likely to have a stronger affinity for technology than the general public. This limitation did not affect the study's main objective – cultural comparison – as it was likely in both samples. Nevertheless, future studies might consider alternative survey modes and sampling strategies that are more likely to achieve representativeness (e.g., face-to-face interviews and probability sampling).

Conclusion

The study highlights the need for a cross-cultural perspective on health prevention measures during the COVID-19 pandemic. The findings suggest that variations across media systems (authoritarian vs. democratic media system) and cultural values (collectivism vs. individualism) make a difference when it comes to perceptions of prevention measures and crises, how they are formed through communication, and how they influence compliance with the prevention measures. Such findings are crucial during a global (health) crisis that is expected to continue to disrupt societies for years to come.

Notes

1. Download rates do not represent active usage. In Switzerland, for example, the number of active SwissCovid apps is only 1.8 million, compared to 3 million downloads.
2. Acceptance refers to a broader context than adoption and includes intention or motivation, as well as adoption or discontinuation in practice (Villius Zetterholm et al., 2021, p. 3).
3. As a prerequisite of the Institutional Review Board, participants were of legal age and, thus, older than 21 years in Singapore and 18 years in Switzerland.
4. Age was measured by asking an open question. Gender options were male, female, and other; the last was recoded randomly into female or male (1 = *female*; 0 = *male*). We measured education level by asking for respondents' highest level of school completed; the categories reflected the education systems in Singapore and Switzerland were recoded into 1 = *university degree*, 0 = *less than university degree*.

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