6-18-2022

Drivers of Adoption of Contact Tracing Mobile Applications

Cristina A. Mihale-Wilson
Goethe University Frankfurt, mihale-wilson@wiwi.uni-frankfurt.de

K. Valerie Carl
Goethe University Frankfurt, kcarl@wiwi.uni-frankfurt.de

DRIVERS OF ADOPTION OF CONTACT TRACING MOBILE APPLICATIONS

Research Paper

A. Cristina Mihale-Wilson, Goethe University Frankfurt, Frankfurt am Main, Germany, mihale-wilson@wiwi.uni-frankfurt.de

K. Valerie Carl, Goethe University Frankfurt, Frankfurt am Main, Germany, kcarl@wiwi.uni-frankfurt.de

Abstract

Contact Tracing Mobile Apps emerged as a new IT-enabled tool with the potential to slow down infection COVID-19 transfers and thus save lives. However, despite their inherent capability to make a substantial technical contribution to fighting the pandemic, the adoption of CTMAs lags behind expectations. Against this background, our work seeks *to produce a systematic and nuanced understanding of hitherto unconsidered yet significant determinants of CTMA adoption. On a more general note, we seek to derive valuable insights that can support decision-makers to accelerate CTMAs' adoption. Based on a large-scale study with 1,027 participants, we present new contextualized determinants that explain individuals' decision to adopt CTMAs. We also find that early in the process of adopting CTMAs, decision-makers have several levers at their disposal to influence the adoption of CTMAs. In contrast, decision makers' ability to influence individuals' adoption of CTMAs is more limited at later stages of the process.*

Keywords: Contact Tracing Mobile Apps; Technology Adoption; Intention-Behavior Gap; UTAUT

1 Introduction

Amidst the ongoing COVID-19 pandemic, Coronavirus transmissions occur mainly through direct, indirect, or close contact with infected people (WHO 2020). Because the disease can be completely asymptomatic, it is imperative to identify and inform those who have been in contact with the infected as fast as possible. *Contact Tracing Mobile Apps (CTMAs)* leverage technology to track and store individuals' movements and contacts. When CTMA users report positive test results in the app, past contacts can be anonymously informed about the possibility of having caught the virus. This way, the contacts of the warning users can get tested and stay at home to avoid spreading the virus to others.

Albeit CTMAs' potential to slow down the spread of the Coronavirus by disrupting the virus transmission chains, and despite such apps' potential effectiveness, ease of use, and in some cases also, privacy friendliness, adoption rates remain low (Sharma et al. 2020). Recent literature on CTMA adoption reports privacy concerns as the main issue hindering their mass adoption (e.g., Chan and Saqib 2021; Garrett et al. 2020; Seto et al. 2021; Sharma et al. 2020). However, as the case of rather privacy-friendly CTMAs shows (Sharma et al. 2020)—e.g., the German CTMA CoronaWarnApp—privacy friendliness is not enough to foster such apps' adoption. Accordingly, the main drivers of CTMA adoption are not yet fully unraveled (Trang et al. 2020). In line with these observations, our work seeks *to produce a systematic and nuanced understanding of hitherto unconsidered yet significant determinants of CTMA adoption.* On a more general note, we seek to derive valuable insights that can support decision-makers to accelerate CTMAs' adoption. Although this research objective is highly practice-relevant, it undeniably deserves our full scholarly attention. After all, CTMA's usefulness hinges on its user base (Seto et al. 2021). The more individuals use such CTMA to warn others, the higher their effect in stopping infection chains in society. Against the background that slowing down the spread of the virus can save lives, there is a legitimate broad interest in finding ways and measures that can promote the mass adoption of such artifacts.

Formally, this work is structured as follows: in the next section, we discuss prior studies on CTMA adoption and present relevant theories that form our research model. Moreover, after discussing our study design and sample, we present our results. Finally, we conclude with a discussion of the main insights, our main theoretical and practical contribution, and the study's limitations.

2 Related Work and Theoretical Background

To address our research goal, we turn to established adoption theories and recent calls for more contextualized research (Burton-Jones and Volkoff 2017; Ho et al. 2020). Generally, research on technology adoption is one of the most mature streams in Information Systems (IS) literature (Ho et al. 2020; Hoehle et al. 2012). Thus, we can currently draw on various established technology adoption models and a rich body of knowledge on the topic. Although these established models have proven very useful to explain individuals' adoption intention and behavior of particular technology on numerous occasions, they are sometimes too general to accurately capture other potentially important factors explaining users' adoption decisions (Burton-Jones and Volkoff 2017; Orlikowski and Iacono 2001). Because, in reality, technology adoption and use do not happen in a vacuum but rather in a particular context, logic dictates that context should be incorporated in technology adoption and use research. However, a contextual perspective on technology adoption may limit the generalizability of the results (Hong et al. 2014). Despite this trade-off between a general versus a contextual perspective on technology adoption, and given the severity of the pandemic and the vital role CTMA can play in its control, it seems appropriate to consider CTMA adoption in context (Trang et al. 2020).

2.1 Prior Studies on CTMA Adoption

Amidst the yet ongoing COVID-19 pandemic, governments worldwide implemented CTMAs as part of their efforts to control the spread of the virus (Seto et al. 2021; Trang et al. 2020). As CTMAs were launched in various countries, scholars also started to investigate the public's attitudes towards such apps (e.g., Horvath et al. 2022), vetted the design decisions for such apps (e.g., Trang et al. 2020), or explored CTMAs adoption (e.g., Seto et al. 2021; Sharma et al. 2020). Interestingly, existing research is mainly focused on the privacy aspects of digital contact tracing. For instance, Horvath and colleagues (2022) investigate citizens' attitudes towards CTMAs in relation to their concerns about data privacy and security breaches. Likewise, Seto et al. (2021) discuss the trade-off between privacy and tracing effectiveness and how getting the right balance could impact CTMA's adoption rates. On a similar note, Chan and Saqib (2021) investigate how privacy concerns can explain unwillingness to download and use CTMAs depending on whether COVID-19 concerns are high or not.

Besides a heavy focus on the privacy aspect of digital contact tracing, prior literature presents insights on CTMA adoption in a piece-meal fashion rather a holistic way. While scholars agree that privacy concerns are only one of many factors driving CTMA adoption (e.g., Chan and Saqib, 2021), very few combine and investigate various potential determinants into a comprehensive framework. One notable exception is Sharma and colleagues' work (2020), which draws on numerous established theories to develop a framework to explain individuals' intention to adopt CTMAs. Despite its commendable efforts, Sharma et al.'s study (2020) does not go beyond individuals' intention to adopt. This is problematic since, to date, various scholars have shown that there are numerous reasons why individuals' intentions do not always translate into action (e.g., Bhattacherjee and Sanford 2009; Maier et al. 2012). Juxtaposing polling results on individuals' intention to adopt CTMAs and actual app uptake reveals that this is also the case for CTMAs. With polling evidence that individuals report an intention to adopt but ultimately do not install them (e.g., Garrett et al. 2020; Walrave et al. 2020), there is a dire need of understanding not only what drives adoption intentions but also what determines or hinders individuals actually to install and use CTMAs. Against this background, in this work, we view technology adoption as a three-stage process (comprising an attitude formation stage, an adoption intention stage, and an actual uptake) and investigate the drivers of CTMA adoption for all three stages of the adoption process individually. Additionally, aiming to derive actionable insights which can inform decision-makers on how to improve CTMA adoption at all stages, we follow Trang et al. (2021) and pay a close look at the context in which CTMA emerged and are used.

2.2 Contextualized Perspective on CTMA Adoption

The importance of context in investigating various phenomena received much attention in the management literature (Hong et al. 2014). In this discipline, *context* is a multifaceted construct (Johns 2006) that can be defined as a "*set of factors surrounding a phenomenon that exert some direct or indirect influence on it*" (Whetten 2009, p. 31). In IS, however, *context* refers to (a) *characteristics of the technology artifact itself* and (b) the *situational factors that impact the technology artifact adoption and usage* (Hong et al. 2014).

In terms of *unique characteristics that CTMAs have*, it is notable that once installed and running, such apps do not require further user engagement. Besides positively tested individuals having to report positive test results in the app, the warning of the contacts at risk of having caught the virus occurs automatically, without any of the users' additional involvement. Another characteristic is that CTMAs are utilitarian apps with few personalization features. While individuals can sometimes report their vaccination status or positive test results in such apps, the main features are "one size fits all" and cannot be changed. Also, please note that CTMAs do not spare their users from catching the virus in the first place but help reduce the spread of the disease to others. Hence, CTMAs are adopted by individuals not only for their own benefit (e.g., to be informed about a potential infection) but also for the protection of other members of society (Trang et al. 2020). Viewing CTMAs as "*socially beneficial*" artifacts—i.e., artifacts that users adopt not only for their own benefit but also because it benefits the individuals around them—suggests that individuals' motivational base for adopting and using such apps entails some altruistic or pro-social component. Ultimately, CTMAs can only function if individuals allow them to use their data (Trang et al. 2021), so any investigation of CTMAs adoption also needs to incorporate the privacy aspects of digital contact tracing.

Regarding *situational factors that impact the technology artifact adoption and usage*, it is notable that CTMAs emerged from the need to address the adverse effects of an external shock. Individuals react to such shocks, sometimes irrational, and have very different coping mechanisms to handle the stress of the situation. Some deny the COVID-19 problem. Some turn to conspiracy theories. Others are aware of the dangers of the pandemic and cooperate fully with government lead efforts to combat the spread of the virus. Individuals' cognitive response to the pandemic might, amongst others, depend on their personal circumstances—i.e., individuals' lifestyle (i.e., whether they use public transportation or not; whether they have a job that raises the chances of contracting the disease), their responsibilities (i.e., whether they are responsible for groceries), and ultimately health status (i.e., whether they are at higher risk when contracting the disease).

3 Conceptual Framework and Hypotheses Development

We employ our contextualized perspective on CTMA adoption to extend general technology adoption models and account for the inherent characteristics and unique context of CTMAs. The core component of our research is the well-established Unified Theory of Acceptance and Use of Technology (UTAUT) by Venkatesh et al. (2003). The rationale for choosing UTAUT as our core technology acceptance model rests upon its comprehensiveness and ability to depict all three technology adoption stages (i.e., attitude formation, intention formation, and actual uptake).

Following Venkatesh et al. (2003), technology adoption and use are determined by individuals' *performance expectancy of the artifact*, their *effort expectancy*, individuals' *social environment*, and *facilitating conditions* (Venkatesh et al. 2003). While performance expectancy refers to individuals' beliefs that using the target technology will advance their goals (i.e., Perceived Usefulness), effort expectancy represents individuals' perception of the artifact's ease of use (PEoU). Social influences (also referred to as "subjective norms" (Brown et al. 2010)) relate to individuals' beliefs that adopting technology will enhance their status within a relevant peer group (Maruping et al. 2017). Extant literature corroborates the link between important stakeholders and individuals' technology adoption intention (Brown et al. 2010). This link is powerful for novices (i.e., individuals with no prior experience with the target technology) and within the work-related context when others (e.g., supervisors, colleagues) can exert some pressure on the potential adoption candidate (Maruping et al. 2017). Finally, facilitating conditions refer to objective factors that make technology use possible—i.e., technical and organizational support (Venkatesh et al. 2003).

3.1 Contextualizing UTAUT Constructs to the CTMA Setting

First, we adapt the *performance expectancy* construct to the CTMA context. Specifically, since CTMA's primary goal is to support their user to inform themselves and others about the chances of being infected, CTMA's must not only deliver on their promise to inform people about potential positive contacts but also do so in a reliable manner. Hence, within the context of CTMAs for COVID-19, performance expectancy is likely to comprise individuals' perception of the app's usefulness to interrupt infection transmissions (PU) and its reliability (PR). Prior research corroborated that reliability can be another critical factor influencing technology adoption by shaping individuals' attitudes towards the system assessed (e.g., Wixom and Todd 2005; Xu et al. 2013). Accordingly, we expect that

H1: Perceived reliability will positively affect individuals' intention to adopt the CTMA.

Next, turn to the *facilitating conditions* construct. Generally, facilitating conditions refer to objective factors that make technology use possible. Such aspects could be technical and organizational support (Venkatesh et al. 2003). In the context of CTMA, which are parsimonious and rather passive in use (because CTMAs typically run as a background service on individuals' devices, and such apps inform about potential infectious contacts via a pop-up message), facilitating conditions for technology acceptance and use relates to technology access (i.e., whether individuals' smartphones comply with the minimal requirements for CTMA's installation; and whether they know how to install the application) and individuals' knowledge about such apps. The latter is essential due to the novelty of CTMAs and the unique situation of using such CTMAs. After all, CTMAs were developed because of the COVID-19 pandemic—a crisis that is entirely unknown to most of us. Not knowing that the CTMA exists, how CTMAs can help control the pandemic, how it works, or how individuals' should behave in case they are warned can be critical pieces of information that can help individuals' sense of self-efficacy (i.e., individuals' ability to perform actions to achieve their goals). A higher sense of self-efficacy can, in turn, positively affect individuals' decision to adopt CTMAs (Sharma et al. 2020). Hence, we postulate that:

H2: Individuals' knowledge about CTMAs increases the chances that CTMAs are adopted.

3.2 Extending UTAUT to the CTMA Context

As discussed in Section 2.2, *context* refers to (a) *characteristics of the technology artifact itself* and (b) the *situational factors that impact the technology artifact's adoption and usage.*

CTMAs possess various characteristics that make such apps different from other technology-enabled artifacts that individuals need to or want to adopt in their professional or personal lives. For instance, CTMAs cannot save their user from getting infected and are rather "*socially beneficial*" artifacts—i.e., artifacts that users adopt not only for their own benefit but also because it benefits the individuals around them. Against this background, individuals' motivational base to adopt and use such apps entails some altruistic or pro-social component. Prior literature corroborated that motivational aspects can drive individuals' intention to adopt technology (e.g., Davis et al. 1992; Lee et al. 2005). Hence, in line with CTMAs' social focus and prior literature (e.g., Sharma et al. 2020), we expect that:

H3: Individuals' motivation to inform themselves and others positively influences CTMA adoption.

Regarding *situational factors that impact the technology artifact adoption and usage*, it is notable that CTMAs emerged from the need to address the adverse effects of an external shock. Individuals' reaction to this shock ranges from denial to utter comprehension of the situation. To model individuals' cognitive views and response to the pandemic, we turn to the Construal Level Theory and the concept of *Psychological Distance* (PD).

In essence, the Construal Level Theory (CLT) explains individuals’ mental grasp (i.e., abstract or concrete) or psychological distance (PD) to objects or events (Liberman and Trope 1998; Trope and Liberman 2010). Psychological distance (PD) is a multidimensional construct entailing a temporal, spatial, social, and hypothetical dimension (Trope and Liberman 2010). In detail, the temporal dimension of PD relates to individuals’ expectations of “*when*” a specific event will occur. The spatial dimension entails individuals’ beliefs of “*where*" the event will happen. The social dimension refers to "*whom*” will a specific event occur, while hypothetically relates to individuals’ beliefs on the “probability” or “*whether*" a particular event will occur (Trope and Liberman 2010). Altogether the four dimensions capture individuals' perception of an event's (e.g., external shocks) existence and perils. Individuals who expect an event will never happen or will happen only far in the future display a high PD level for that event. In contrast, individuals who can mentally envision that the event could occur very soon have a low PD level (Trope and Liberman 2010). Concerning the COVID-19 pandemic, psychological distance describes the extent to which individuals view a potential infection with the Coronavirus as concrete or abstract. Since individuals' psychological distance profoundly affects how they evaluate and perceive events, PD can be essential in determining technology adoption (Ho et al. 2020; Trope and Liberman 2010). Because individuals with high PD levels see an event or potential threat as abstract (i.e., unlikely to happen), we expect a negative relationship between PD and CTMA adoption. Accordingly, we postulate that:

H4: PD influences CTMA adoption negatively.

Other important situational determinants of CTMA adoption are individuals’ *personal circumstances* such as their lifestyle (i.e., whether they use public transportation or not; whether they have a job that raises the chances of contracting the disease), their responsibilities (i.e., whether they are responsible for groceries), and ultimately health status (i.e., whether they are at higher risk when contracting the disease). In line with Sharma et al. (2020), we expect that, for instance, individuals with a poor health status instance more willing to share their data and contacts with others and are more interested in knowing whether they had positive encounters. Similarly, individuals who are frequently exposed to other people—e.g., because they use public transport or go to grocery stores—will be more likely to be interested in potential positive encounters and thus more likely to adopt such apps. Based on these notions, we postulate that:

H5: Personal circumstances will significantly influence CTMA adoption.

Figure 1 visualizes our research model, which entails the contextualized and extended version of UTAUT to fit the CTMA setting. Additionally, it controls for variables other essential determinants of CTMA adoption, such as individuals' age, gender, and privacy concerns (Chan and Saqib 2021; Garrett et al. 2020; Seto et al. 2021; Sharma et al. 2020).

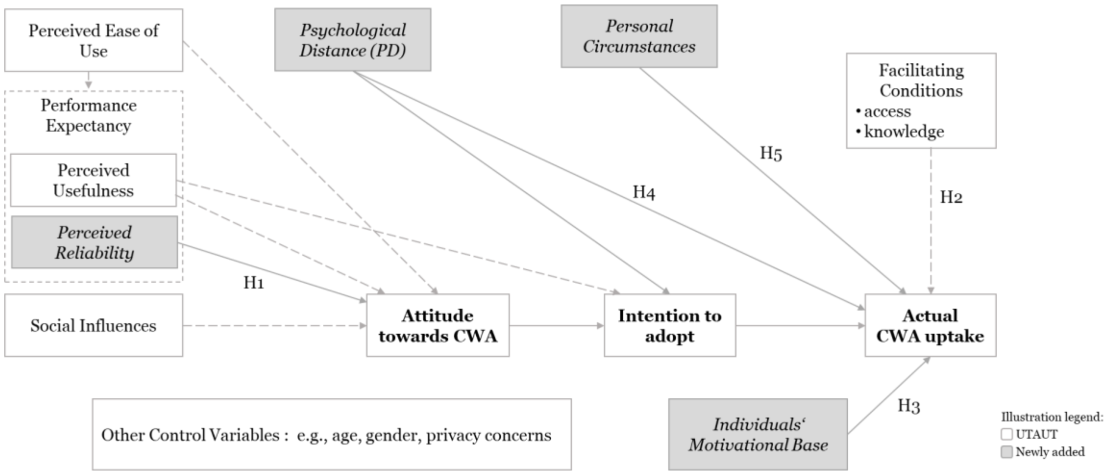

Figure 1. Research model.

3.3 Study Setting, Design, and Sample

We conduct a large-scale online-administered study with 1,819 individuals from Germany to test our hypotheses. Our main subject of investigation is the German Corona-Warn-App (CWA). This research setting and, in particular, CWA seem to be promising for analyzing CTMA adoption for several reasons: First, the app is used voluntarily. Second, when the study was conducted, the CWA ran only on Android and iOS Smartphones, with relatively new versions of the most widespread operating systems. Accordingly, the German setting allows us also to identify the effect of missing technology access for its adoption. Third, the CWA cannot be used for other purposes (e.g., for quarantine surveillance) than contact tracing. The app is, by various standards, privacy-friendly. Data is saved decentralized and anonymously, compliant with the European General Data Protection Regulation. Also, the CWA is connected with CTMAs from other European countries.

The constructs of the research model were operationalized based on measurement scales derived from prior literature. Table 1 presents an overview of the used measures.

Construct	Items [measurement scales]	Source
Performance expectancy	*Perceived Usefulness*: The CWA can help to fight the pandemic. [1-strongly disagree; 7-strongly agree] *Perceived Reliability*: The CWA operates reliably. [1-strongly disagree; 7-strongly agree]	(Davis 1989; Venkatesh et al. 2003)
Perceived Ease of Use	Using the CWA is very complicated. [1-strongly disagree; 7-strongly agree]	
Psy-chological distance	*When*: Assess the period of time in which you consider a coronavirus disease of yourself to be most likely. [1-immediately (< 1 month); 5-not at all] *Whether:* How concerned are you that you could be infected with the Coronavirus yourself? [1-not at all worried; 5-extremely worried] *Where*: Now think about different places you visit during your free time and work. These can be short visits or longer ones. Where could you possibly infect yourself? [1-everywhere; 5-I do not know] *Whom:* How concerned are you in general that more people in Germany could become infected? [1-not at all; 2-extremely concerned]; [Reversed].	(Trope and Liberman 2010)
Motivational base	*Inform one-self:* One uses the CWA primarily to inform oneself about a possible infection [1-strongly disagree; 7-strongly agree]	(Davis et al. 1992)

	Inform others: One uses the CWA primarily to inform others about a possible infection[1-strongly disagree; 7-strongly agree]	
Social influence	My family thinks about the CWA mainly...; My friends think about the CWA mainly...[1-very negative; 7-very positive]	(Kitchens et al. 2020)
Personal cir-cumstances	*Responsibilities* [1- yes; 2-no]: 1. Are you the one in your household who is mainly responsible for regular purchases of daily necessities (e.g., food, drugstore items, etc.)?; 2. Do you care for relatives? *Lifestyle:* Do you currently use public transportation [1-yes; regularly; 3-no] *Health Status:* Do you belong to a risk group? [1-yes; 2-no]	(Benbasat and Zmud 2003; Hong et al. 2014)
Privacy concerns	1. Usually, it bothers me when apps and websites ask me for personal information; 2. I am concerned that apps and websites collect too much personal information about me. [1-strongly disagree; 7-strongly agree]	(Hong and Thong 2013)
Facilitating conditions	*Technology Access* [1- yes; 2 – no]: 1. Do you own a smartphone with an operating system newer than iOS smartphones from iPhone 6s on under iOS 13.5 or Android-based smartphones from Android 6 upwards?; 2. Do you generally download applications to your smartphone? *Knowledge of CWA's features and use* [1-strongly disagree; 7-strongly agree]: 1. Do you know the CWA?; 2. The CWA is available free of charge; 3. For contact tracing in the CWA, location tracking is used, for example, via GPS or the mobile network. [Reversed]; 4. The CWA consumes a large amount of mobile data for its function. [Reversed]; 5. The data stored in the CWA can be used for purposes other than tracing coronavirus infections. [Reversed]; 6. The CWA only processes anonymous data. No conclusions can be drawn about me as a person; 7. The goal of the CWA is to control the population. [Reversed]; 8. The CWA can also access other data on my smartphone. [Reversed]; 9. The CWA is used exclusively to evaluate possible contacts; 10. If I am infected and have reported this via the CWA, I can see which contacts I need to inform. [Reversed];11. The CWA can control the compliance of contact prohibitions. [Reversed]; 12. You can share test results via the CWA, 13. If I am infected with the Coronavirus and have reported this via the CWA, the app is used to monitor my quarantine. [Reversed]; 14. If you have installed the CWA, you have to enter your positive test result there immediately. [Reversed]; 15. If you have installed the CWA and are warned about it, you must immediately go into quarantine. [Reversed]	(Venkatesh et al. 2003) (Verbrauche rzentrale 2021)

Table 1. Measures

The study was conducted as an online administered survey that entailed various attention checks. After the data cleaning process (i.e., check for completeness, response time, and quality checks), the final sample entails 1.027 individuals. 51% of the participants were female, 49% were male. Individuals were spread across all age groups between 18 and 75+. 76% of participants used Android smartphones, 19.2% used iOS, and 1.2% owned devices with other alternative operating systems (i.e., Microsoft).

Related to CTMA adoption behavior, the data reveals three sub-groups of individuals: 463 individuals (45%) are *opponents*—i.e., individuals who do not have any intention to adopt the CWA. 391 participants (38%) are *intentionalists*—i.e., they show a positive intention to adopt the CWA but did not adopt it yet. Ultimately, 173 individuals (17%) are *adopters*—i.e., they already adopted the CWA. Notably, because our study captures individuals' self-reports on independent and dependent variables, we implement various ex-ante strategies (i.e., use of different scales, variability in the location of items) and posthoc tests (i.e., Harmans' single factor test, the Marker Variable technique) to avoid and control for potential Common Method Bias (Podsakoff 2003). Harmans' Single Factor Test reveals that all items can be classified into seven constructs with Eigenvalues greater than 1.0. These constructs explain about 60% of the total variance. Because the first factor only accounts for 19.3% of the variance, we can conclude that CMB is not a concern in our study. However, following Podsakoff et al. (2003), Malhotra et al. (2006), we make use of the Marker Variable (MV) technique. Our marker variable consists of a shortened version of the commonly accepted scale for romanticism. The MV is not theoretically connected to our constructs of interest. Furthermore, to control for potential effects of CMB, we included the MV in our estimation model (Ho et al. 2020). As our results later show, the MV is not statistically significant and corroborates that our study does not suffer from CMB.

4 Analysis Results

For the quantitative part of the study, we use Generalized Structural Equation Modelling (GSEM) in STATA (v16). The GSEM analysis focuses on testing our research model and investigating the determinants of behavioral intention and actual CTMA uptake. This analysis method allows us to estimate the linkages between the various constructs of interest in one estimation step.

Since our data is cross-sectional, it does not reveal if individuals who show a behavior intention do finally adopt. Subsequently, we rely on identifying determinants in behavior intention and determinants of actual adoption by exploiting participants' division into the three previously mentioned sub-groups—adopters, intentionalists, opponents. To analyze the determinants of behavior intention, we estimate our model on the subset of opponents and intentionalists. Similarly, to assess the factors driving adoption and thus understand discrepancies between adoption intentions and actual uptake, we focus on differences between intentionalists and adopters—often referred to as the "Intention-Behavior Gap" (I-B Gap). For both estimations, we use the same model specification. However, we report and discuss the determinants of individuals' intention and actual uptake separately to improve readability.

4.1 Understanding Adoption Intentions

Table 2 presents the results of our GSEM estimations on the subset of opponents and intentionalists. Results represent the *chances of individuals being opponents* rather than intentionalists. Overall, the results endorse the main linkages proposed by prior literature (e.g., PU, PEoU) and corroborate newly proposed determinants of CTMA adoption. Table 2 indicates that PU, PEoU, social influences, knowledge about the CWA, and individuals' privacy concerns drive their attitude towards the app. A positive attitude about the CWA among individuals' family and friends will swap over to the individual herself/himself. Similarly, knowing how the app works, what the app can do (i.e., inform individuals without enforcing quarantine) will also translate into a more favorable attitude towards the app. In contrast, individuals' privacy concerns (i.e., concerns about the unauthorized collection of personal data) negatively influence their attitude towards the app. Then, the results in Column 2 show that individuals' attitude towards the app and facilitating conditions—i.e., being able to install the app—will translate into a higher intention to adopt the CWA. Individuals' age, gender, or education do not significantly influence individuals' intention to adopt or not.

Regarding the newly proposed determinans of CTMA adoption: we find a positive influence of perceived reliability (PR) ($\beta = 0.365$, $p < .000$) on individuals' attitudes towards CTMAs. One unit increase in individuals' perception of CWA's reliability improves her or his attitude towards the app by approximately 44% (=exp[0.365]). A mediation analysis also shows that perceived reliability has an indirect effect on individuals' adoption intention. PR's impact on individuals' adoption intention is fully mediated by their attitude towards the app. Increased perceived reliability of the app decreases the chances of being an opponent ($\beta = -0.283$; 95% Bias Corrected (BC) Confidence Interval with Bootstrap N=1,000 replications = [-.4518083; -.1180845]). Since the BC Confidence Interval does not entail "0", the indirect effect is statistically significant.

We also find that PD has a direct negative effect on individuals' attitude towards the CWA but no effect on individuals' intention to adopt. An increase in individuals' PD level decreases individuals' attitude towards the CWA by about 25% ($\beta = -0.220$, $p < .05$). Mediation analyses estimating PD's effect on individuals' intention to adopt show no statistically significant results. Also, Table 2 shows that neither individuals' motivational base nor their personal circumstances influence the adoption intention.

	(1) DV= Attitude towards CWA		**(2) DV=Opponent (1/0) versus Intentionalist**	
	β	**SE**	**β**	**SE**
Attitude towards the CWA			-0.781***	0.159
Perceived Usefulness (PU)	0.431***	0.083	-0.554***	0.120
Perceived Ease of Use (PEoU)	-0.004	0.092		
Social Influences (SI)	2.014***	0.186		
Knowledge about the CWA	0.649***	0.153	-0.240	0.221
Privacy Concerns	-0.174**	0.061		
Facilitating Conditions: technically unable to install			-1.315***	0.291
Facilitating Conditions: general knowledge to install apps			-0.377	0.207
Marker Variable	-0.140	0.083	0.01	0.095
Further Control Variables: Age, Gender, Education, Number of Kids				
Newly proposed drivers of CTMA adoption				
Perceived Reliability (PR)	*0.365****	*0.078*		
Psychological Distance (PD)	*-0.220**	*0.114*	*0.264*	*0.187*
Main Motivation to use: self-inform			*-0.150*	*0.104*
Main Motivation to use: inform others			*-0.044*	*0.092*
Personal Circumstances: responsible for groceries			*-0.282*	*0.279*
Personal Circumstances: caregiver for other individuals			*0.424*	*0.389*
Personal Circumstances: use of public transport			*-0.349*	*0.186*
Personal Circumstances: the individual is within the risk group			*-0.599*	*0.284*

Table 2. Determinants of individuals' intention to adopt CTMAs
Comparison between subgroups: Opponents and Intentionalists (N=636)
*Significance levels: *** if p-value<0.001, ** if p-value<0.01, * if p-value<0.05*

4.2 Understanding CTMA Uptake

To test the determinants of actual CTMA adoption, we estimated our model on the subset of intentionalists and adopters. Table 3 presents the corresponding estimation results, which show the chances of individuals being only *intentionalists* rather than adopters. This way, it reveals the main determinants of a discrepancy between adoption intention and actual uptake (i.e., I-B Gap).

Again, the estimation results show that PU, PEoU, social influences, and knowledge about the CWA positively influence individuals' attitude towards the CWA. Then, individuals' attitude towards the CWA significantly impacts the chances of actual uptake. Our results show that one level increase in individuals' positive attitude towards the CWA, the chances of being an intentionalist (i.e., individuals are more likely to be adopters) by 67% (β=-1.114, $p<.001$). Similarly, individuals' knowledge about how the app works and what it can do also decreases the chances of being an intentionalist by 69% (β=-1.184, $p<.001$). Ultimately, facilitating conditions can also considerably influence actual CWA uptake. Intuitively, individuals who are technically unable to install the CWA—i.e., because their smartphone does not meet the technical requirements of the CWA—are very likely to stay intentionalists (β=21.31, $p<.001$). Additionally, individuals' knowledge of how to install apps on their smartphones is also driving actual adoption significantly. If participants are able to install apps on their smartphones, the chances of being an intentionalist decrease by 47% (β=-0.628, $p<.001$).

	(1) DV= Attitude towards CWA		**(2) DV= Intentionalist (1/0) versus Adopter**	
	β	**SE**	**β**	**SE**
Attitude towards the CWA			-1.114***	0.275
Perceived Usefulness (PU)	0.552***	0.092	0.212	0.167
Perceived Ease of Use (PEoU)	0.317**	0.088		
Social Influences (SI)	1.530***	0.152		
Knowledge about the CWA	0.546***	0.117	-1.184***	0.185
Privacy Concerns	-0.035	0.083		
Facilitating Conditions: technically unable to install			21.31***	0.941
Facilitating Conditions: general knowledge to install apps			-0.628*	0.237
Further Control Variables: Age, Gender, Education, Number of Kids				
Newly proposed drivers of CTMA adoption				
Perceived Reliability (PR)	*0.528****	*0.100*		
Psychological Distance (PD)	*-0.395***	*0.146*	*-0.094*	*0.377*
Main Motivation to use: self-inform			*-0.223**	*0.111*
Main Motivation to use: inform others			*0.091*	*0.147*
Personal Circumstances: responsible for groceries			*-0.568**	*0.279*
Personal Circumstances: caregiver for other individuals			*-0.369*	*0.549*
Personal Circumstances: use of public transport			*0.570***	*.248*
Personal Circumstances: the individual is within the risk group			*0.314*	*0.438*

Table 3. Determinants of individuals' actual adoption of CTMAs
Comparison between subgroups: Intentionalists and Adopters (N=564)
*Significance levels: *** if p-value<0.001, ** if p-value<0.01, * if p-value<0.05*

Regarding the newly postulated drivers of CTMA adoption: Individuals' PR of the app increases individuals' attitude towards the app by 70% (β=0.528, p<.001). Additionally, PR indirectly influences individuals' decision to install the CWA through individuals' attitude towards the app. Mediation analyses show that an increase in individuals' perceived reliability of the CWA will decrease the chances to stay an intentionalist by 44% (β =-0.588; 95% Bias Corrected (BC) Confidence Interval gained with Bootstrap N=1,000 replications = [-0.9047528; -0.2956275]).

Simultaneously, the data corroborate that PD negatively influences individuals' attitude towards the app. An increase in individuals' PD level by one unit decreases their positive attitude about the app by 67% (β=-0.395, p<.05). The results show no statistically significant direct effect of PD on individuals' actual uptake. However, mediation analyses revealed a significant indirect effect of PD on actual CWA adoption through individuals' attitude towards the CWA. An increase in PD's level increase the chances of being an intentionalist rather than adopter by approximately 55% (β =0.440; 95% Bias Corrected (BC) Confidence Interval gained with Bootstrap N=1,000 replications = [0.0859519; 0.8604848]).

Besides the discussed insights, the estimation results show that individuals' intrinsic motivation would positively influence CWA uptake. In this vein, Column 2 indicates that individuals' intrinsic motivation to use the app to inform primarily themselves decreases the chances of being an intentionalist (i.e., individuals are more likely to be adopters) by 20% (β = -0.223, p<.05).

Similarly, results support the postulated link between personal circumstances and CTMA adoption. In this regard, the estimations reveal that personal responsibilities such as grocery shopping can reduce the chances of being an intentionalist (i.e., increase the chances of being an adopter) by 44% (β = -0.568, p<.05). In contrast, lifestyle-dependent activities such as the use of public transportation can increase the chances of remaining an intentionalist. Hereby, Table 3 Column 2 reveals that individuals who use public transport are 76% more likely to be intentionalists instead of adopters ($\beta = 0.570$, $p<.01$).

5 Conclusion

This work's main goal was *to produce a systematic and nuanced understanding of hitherto unconsidered yet significant (and contextual) determinants of CTMA adoption.* Based on prior literature and a contextualized perspective of CTMA adoption, we extend the general UTAUT model and propose new determinants of CTMA adoption. Altogether, our work contributes to both research and practice. Because our ultimate goal of the study is to use the newly identified determinants of CTMA adoption in support of decision-makers to accelerate CTMAs' mass adoption, we will first discuss our findings' practical contributions before turning to the theoretical contributions of this work.

5.1 Practical Contributions

Due to the severity of the pandemic across the globe and the potential usefulness of CTMA to help control the pandemic, there is a legitimate broad interest in finding ways and measures that can promote mass adoption of such artifacts. Our work supports decision-makers seeking to foster the mass adoption of CTMAs in two ways: First, our work provides a general understanding of the context-specific elements that significantly shape CTMA adoption. Our study shows that: Perceived reliability will positively affect individuals' intention to adopt the CTMA (H1). Individuals' knowledge about the CTMA will improve the chances of actual uptake and individuals' attitude towards CTMAs (H2). Interestingly, individuals' intrinsic motivation to inform themselves and others positively influences the chances of actual CTMA adoption (H3). Regarding individuals' PD to the pandemic, our results show that PD has a statistically significant negative impact on individuals' attitude towards the CTMA and their downstream decision to install the app but no significant effect on individuals' intention to adopt (H4). Ultimately, our data shows that personal circumstances do not affect intentions to adopt but do influence actual CTMA uptake statistically (H5). Based on these insights, our work informs decision-makers on the elements they need to focus on in their endeavor to improve CTMAs' mass adoption.

Second, by strictly distinguishing between three stages of the technology adoption process, our work indicates that some determinants only affect individuals' intention to adopt but not their actual uptake or vice versa. Hence, under the premise of limited resources and the fact that time is of the essence when combating the pandemic, our work indicates how CTMAs adoption can be optimized. In this regard, our work reveals which determinants of CTMA adoption decision-makers need to focus on, at what stage in the CTMA adoption process. Please note that our insights and suggestions are rather strategic and should help decision-makers develop optimal and resource-effective plans to foster CTMA mass adoption. Unfortunately, based on our works' focus, we cannot derive concrete and detailed action plans for optimally transferring our recommendations into practice. After all, various means and actions can be taken to implement our recommendations into practice. Therefore, investigating which actions are the most effective ones goes beyond the scope of our work. This being said, our work provides various strategic recommendations for decision-makers responsible for fostering CTMA adoption:

Given the already widely established relationship between attitudes towards an artifact, individuals' intention to adopt, and their actual uptake behavior, our results indicate that at the beginning of the CTMA adoption phase (for instance, when CTMAs have been or will be shortly released), decision-makers need to focus on conveying CTMAs usefulness, endowing individuals with knowledge about CTMAs (e.g., how it works, what are its specs, how to behave in case of alerts) and address potential privacy concerns. Admittedly, to date, there is a lot of knowledge available about CTMAs and the CWA in particular. However, such knowledge is mainly disseminated via a "pull" approach rather than a "push" approach. Because with the "pull" approach, information is available only to those who know where to search for it and make an effort to do so, the "push" approach would benefit more individuals. Our data show that the more individuals know about how the CWA works and what it can do and cannot do, the better individuals' attitude towards the app.

Accordingly, improving CTMAs adoption might entail disseminating CTMA information over the push approach to the masses.

Besides the mentioned directions, at the earlier stage of CTMA adoption, it is also expedient to focus on decreasing individuals' PD to the pandemic. Prior literature shows that individuals' PD—i.e., whether they view events as abstract or concrete—is malleable (e.g., Ho et al. 2020). Accordingly, by convincing individuals that catching the virus is a real option that can apply to anyone in the near future, the chances of uptake can improve individuals' attitude towards the app and ultimately later translate into higher chances of actually installing and using CTMAs.

For the later stages of CTMAs' adoption process, it is notable that only PR significantly influences individuals' intention to adopt and their actual CTMA uptake. Accordingly, our work reveals that decision-makers have various levers to improve CTMAs' mass adoption at the beginning of the CTMA adoption process. However, once the initial chance to shape individuals' attitudes towards CTMAs has passed, decision-makers' influence on individuals' intention to adopt and actual uptake is limited to conveying CTMAs' reliability in achieving its purpose. This insight highlights the importance of putting most efforts into improving the early stage of CTMAs adoption.

5.2 Theoretical Contributions

From a theoretical perspective, our study enriches the extant technology adoption literature by proposing various new extensions for UTAUT. These extensions encompass CTMAs' usage context. Prior research on technology adoption spawns a variety of technologies (e.g., social media, online forums, mobile banking, health care apps), with different user groups (e.g., employees, physicians, students), in different organizational settings (e.g., hospitals, public agencies, corporations) and countries (e.g., USA, India, Germany). However, extant literature undergoes the importance of context (Ho et al. 2020; Johns 2006) in favor of generalizability. Albeit this is legitimate and expedient in some cases, in others—such as in the case at hand or for other socially beneficial apps—it might be worth paying more attention to the artifact and its usage context and forgo generalizability. Thus, based on this notion, our work's most interesting insight is that individuals' PD is an important contextual determinant of CTMA adoption. This way, our work contributes to understanding what drives the adoption of socially beneficial artifacts—i.e., artifacts benefitting their user but even more so the society or individuals around them. Besides CTMAs, which can help control the spread of airborne viruses such as the Coronavirus, further socially beneficial apps can be but are not limited to: apps for physical and mental health, disaster warning apps, sustainability, and climate protection apps (such as CO_2 tracking apps, water, and energy consumption trackers). To date, knowledge about individuals' adoption of socially beneficial artifacts focuses on sustainable consumption, climate protection, and health improving apps. Our study extends the current knowledge on such apps by showing the drivers of adoption for digital contact tracing apps. This way, we enable future investigations of whether various types of socially beneficial apps have similar or different drivers of adoption.

Another contribution of this work is that it proves the merit of dividing and considering technology adoption research as a three-stage process. To date, there is very little research exploring technology adoption by investigating attitude formation, intention formation, and actual uptake simultaneously, in one model, but strictly separated from each other. By adopting this split, our work gains more nuanced insights in each adoption phase and captures the drivers of the so often observed discrepancies between individuals' intentions and actual adoption behavior (Bagozzi 2007; Venkatesh et al. 2003).

Moreover, this study also extends past research by investigating how PD affects technology adoption. Surprisingly, most past studies considered individuals' mental grasp of objects and events in terms of "mental construal" rather than psychological distance when discussing individuals' preference reversals or technology adoption (e.g., Ho et al. 2020; Todorov et al. 2007). Although exploring individuals' construal is legitimate and valuable, this concept is more subjective and inherently relative when compared to the more objectively operationalizable PD construct (Liberman et al. 2007).

5.3 Limitations and Future Research Directions

Despite our best efforts to ensure the study's reliability and validity, our study does not come without limitations. Two notable limitations of our work are its focus on German participants and the German Corona Warn App. Since individuals with different cultural backgrounds are likely to have different views on privacy-related issues and might live in countries that are more or less impacted by the COVID-19 pandemic, some drivers of CTMAs adoption might become more salient, and others less important. Furthermore, considering the plethora of possibilities for designing and implementing voluntary use CTMAs, understanding CMTAs' mass adoption will require additional studies with various app architectures. Against this background, future research on CTMA adoption should use our study as a stepping stone to investigate drivers of CTMA adoption based on data from other countries and with different other CTMAs. This path for future research will allow us to create better and more powerful CTMAs for this and future pandemics. Another limitation of our work is that it is cross-sectional. Hence, it does not reveal if individuals who show a behavior intention do finally adopt. To address this shortcoming, in our work, we rely on identifying determinants in behavior intention and determinants of actual adoption by exploiting participants' division into adopters, intentionalists, and opponents. Besides the validity of our approach, future research should try to investigate CTMA adoption in a longitudinal setting. After all, as the COVID-19 pandemic continues to rage around the world, vaccination progress is very heterogeneous across the worlds' regions, and experts predict that various pandemics will hit us in the future; understanding and improving the mass use of CTMAs is proving to be a matter of interest for now and for the future.

References

Bagozzi, R. P. (2007). "The Legacy of the Technology Acceptance Model and a Proposal for a Paradigm Shift." *Journal of the Association for Information Systems* 8 (4), 244–254.

Benbasat, I. and Zmud, R. W. (2003). "The Identity Crisis within the Is Discipline: Defining and Communicating the Discipline's Core Properties." *MIS Quarterly* 27 (2), 183–194.

Bhattacherjee, A. and Sanford, C. (2009). "The Intention–Behaviour Gap in Technology Usage: The Moderating Role of Attitude Strength." *Behaviour & Information Technology* 28 (4), 389–401.

Brown, S. A., Dennis, A. R. and Venkatesh, V. (2010). "Predicting Collaboration Technology Use: Integrating Technology Adoption and Collaboration Research." *Journal of Management Information Systems* 27 (2), 9–54.

Chan, E. Y. and Saqib, N. U. (2021). "Privacy Concerns Can Explain Unwillingness to Download and Use Contact Tracing Apps When COVID-19 Concerns Are High." *Computers in Human Behavior* 119, 106718.

Davis, F. D. (1989). "Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology." *MIS Quarterly* 13 (3), 319–340.

Davis, F. D., Bagozzi, R. P. and Warshaw, P. R. (1992). "Extrinsic and Intrinsic Motivation to Use Computers in the Workplace." *Journal of Applied Social Psychology* 22 (14), 1111–1132.

Garrett, P. M., White, J. P., Lewandowsky, S., Kashima, Y., Perfors, A., Little, D. R., Geard, N., Mitchell, L., Tomko, M. and Dennis, S. (2021). "The Acceptability and Uptake of Smartphone Tracking for COVID-19 in Australia." *PLOS ONE* 16 (1), e0244827.

Ho, C. K. Y., Weiling K., Hefu L. and Chau, P. Y. K. (2020). "Separate Versus Joint Evaluation: The Roles of Evaluation Mode and Construal Level in Technology Adoption." *MIS Quarterly* 44 (2), 725–746.

Hong, W., Chan, F. K., Thong, J. Y., Chasalow, L. C. and Dhillon, G. (2014). "A Framework and Guidelines for Context-Specific Theorizing in Information Systems Research." *Information Systems Research* 25 (1), 111–136.

Hong, W. and Thong, J. Y. L. (2013). "Internet Privacy Concerns: An Integrated Conceptualization and Four Empirical Studies." *MIS Quarterly* 37 (1), 275–298.

Horvath, L., Banducci, S. and James, O. (2022). "Citizens' Attitudes to Contact Tracing Apps." *Journal of Experimental Political Science* 9 (1), 118–130.

Johns, G. (2006). "The Essential Impact of Context on Organizational Behavior." *The Academy of Management Review* 31 (2), 386–408.

Kitchens, B., Johnson, S. L. and Gray, P. (2020). "Understanding Echo Chambers and Filter Bubbles: The Impact of Social Media on Diversification and Partisan Shifts in News Consumption." *MIS Quarterly* 44 (4), 1619–1650.

Lee, M. K. O., Cheung, C. M. K. and Chen, Z. (2005). "Acceptance of Internet-Based Learning Medium: The Role of Extrinsic and Intrinsic Motivation." *Information & Management* 42 (8), 1095–1104.

Liberman, N. and Trope, Y. (1998). "The Role of Feasibility and Desirability Considerations in near and Distant Future Decisions: A Test of Temporal Construal Theory." *Journal of Personality and Social Psychology* 75 (1), 5–18.

Liberman, N., Trope, Y. and Wakslak, C. (2007). "Construal Level Theory and Consumer Behavior." *Journal of Consumer Psychology* 17 (2), 113–117.

Maier, C., Laumer, S., Eckhardt, A. and Weitzel, T. 2012. Using User Personality to Explain the Intention-Behavior Gap and Changes in Beliefs: A Longitudinal Analysis. In: *Proceedings of the Thirty Third International Conference on Information Systems (ICIS)*, Orlando, FL, US.

Malhotra, N. K., Kim, S. S. and Patil, A. (2006). "Common Method Variance in IS Research: A Comparison of Alternative Approaches and a Reanalysis of Past Research." *Management Science* 52 (12), 1865–1883.

Maruping, L. M., Bala, H., Venkatesh, V. and Brown, S. A. (2017). "Going beyond Intention: Integrating Behavioral Expectation into the Unified Theory of Acceptance and Use of Technology." *Journal of the Association for Information Science and Technology* 68 (3), Wiley Online Library, 623–637.

Orlikowski, W. J. and Iacono, C. S. (2001). “Research Commentary: Desperately Seeking the ‘IT’ in IT Research—A Call to Theorizing the IT Artifact.” *Information Systems Research* 12 (2), 121–134.
Podsakoff, N. P. (2003). “Common Method Biases in Behavioral Research: A Critical Review of the Literature and Recommended Remedies.” *Journal of Applied Psychology* 88 (5), 879–903.
Seto, E., Challa, P. and Ware, P. (2021). “Adoption of COVID-19 Contact Tracing Apps: A Balance Between Privacy and Effectiveness.” *Journal of Medical Internet Research* 23 (3), e25726.
Sharma, S., Singh, G., Sharma, R., Jones, P., Kraus, S. and Dwivedi, Y. K. (2020). “Digital Health Innovation: Exploring Adoption of COVID-19 Digital Contact Tracing Apps.” *IEEE Transactions on Engineering Management* 1–17.
Todorov, A., Goren, A., and Trope, Y. (2007). “Probability as a Psychological Distance: Construal and Preferences.” *Journal of Experimental Social Psychology* 43 (3), 473–482.
Trang, S., Trenz, M., Weiger, W. H., Tarafdar, M. and Cheung, C. M. K. (2020). “One App to Trace Them All? Examining App Specifications for Mass Acceptance of Contact-Tracing Apps.” *European Journal of Information Systems* 29 (4), 415–428.
Trope, Y. and Liberman, N. (2010). “Construal-Level Theory of Psychological Distance.” *Psychological Review* 117 (2), 440–463.
Venkatesh, V., Morris, M. G., Davis, G. B. and Davis, F. D. (2003). “User Acceptance of Information Technology: Toward a Unified View.” *MIS Quarterly* 27 (3), 425–478.
Verbraucherzentrale. (2021). *Corona-Warn-App: Fragen und Antworten zur deutschen Tracing-App*. URL: https://www.verbraucherzentrale.de/wissen/digitale-welt/apps-und-software/coronawarnapp-fragen-und-antworten-zur-deutschen-tracingapp-47466/ (visited on April 29, 2021).
Whetten, D. A. (2009). “An Examination of the Interface Between Context and Theory Applied to the Study of Chinese Organizations.” *Management and Organization Review* 5 (1), 29–56.
World Health Organization (WHO). (2020). *Transmission of SARS-CoV-2: Implications for Infection Prevention Precautions*. URL: https://www.who.int/news-room/commentaries/detail/transmission-of-sars-cov-2-implications-for-infection-prevention-precautions/ (visited on November 22, 2020).
Wixom, B. H. and Todd, P. A. (2005). “A Theoretical Integration of User Satisfaction and Technology Acceptance.” *Information Systems Research* 16 (1), 85–102.
Xu, J. (David), Benbasat, I. and Cenfetelli, R. T. (2013). “Integrating Service Quality with System and Information Quality: An Empirical Test in the E-Service Context.” *MIS Quarterly* 37 (3), 777–794.