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Resistance to contact tracing applications: The implementation process in a social context

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ABSTRACT

The success of new technologies such as contact tracing mobile applications depends on large-scale end-user adoption. However, the implementation may encounter resistance, since the uncertainty surrounding novel technology may raise anxiety, and persuasion efforts to promote use can evoke reactance. Thereby, anxiety and reactance are two forms of resistance to new technology. Little is known about the role of resistance over the course of the innovation implementation process, in a social environment where technology functionality depends on adoption by others. Therefore, this four-wave longitudinal study followed adoption of the Dutch COVID-19 contact tracing app during four months ($N = 1120$), and explored the time dynamics and interplay of reactance to freedom threat, anxiety, and perceived social norms on app use. Mixed-effect analyses showed that anxiety and, subtly, reactance decreased with time; initial freedom threat predicted later reactance. App use related negatively to reactance and anxiety; and positively to positive social norms. Over time, the norm effect was mediated by lower reactance and anxiety. The results imply that resistance is pervasive, suggest that self-perceived app use norms may be key to overcoming resistance to new applications, and demonstrate that theories predicting innovation or technology acceptance benefit from studying predictors over time.

1. Introduction

A most important step in implementing new technologies is potential users starting to use it (Rogers, 2003). Widespread adoption is particularly important if part of the technology's functionality depends on wide diffusion (such as social media, and health or activity trackers with social comparison or competition features), or even requires mass acceptance for success. The latter is the case for contact tracing applications (CTAs) that can be downloaded on a smartphone and detect if someone is near another user of the same app for a specified duration, such as has been introduced in fighting the current COVID-19 (SARS-CoV-2) pandemic. CTAs can help to reduce the spread of the virus at a relatively low adoption rate of 20% (Jenniskens et al., 2021), but their contribution increases substantially with higher adoption rates (Kretzschmar et al., 2020; Wymant et al., 2021). The adoption rates recommended for effectiveness by simulations are structurally higher than the observed CTA adoption rates across countries (Kahnbach et al., 2021).

Slow diffusion and low adoption rates of a new technology are no exception (e.g., Chiesa & Frattini, 2011). Part of the population may have practical reasons not to adopt the technology (e.g., no phone), but this does not explain the hesitancy or rejection of the majority of potential users. For them, starting to use a new technology involves a behaviour change. Consequently, from a psychological behaviour-change perspective, low adoption can be explained by overall resistance, a motivational state to avoid the effects of change (Knowles & Riner, 2007). For instance, when being introduced to the new technology, resistance may take the form of anxiety of new technologies (Mani & Chouk, 2018), which needs to be overcome before people start seriously considering using it (Heidenreich et al., 2016). To mitigate this initial resistance, new technologies are usually introduced with

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advertisements or campaigns (i.e., persuasive appeals), but these may be counter-effective. Although persuasive attempts are a logical step to speed up the diffusion and to increase adoption rates, they themselves can evoke resistance in the form of reactance because people do not want to be influenced (Fransen et al., 2015; Knowles & Riner, 2007). Indeed, reactance has been detected as response to the introduction of a COVID-19 CTA (Lavorgna et al., 2021). This potentially leads to less adoption. Thus, the end-users' resistance throughout the implementation process is an important piece of the puzzle to understand the diffusion of new technologies (Mani & Chouk, 2018).

The present study investigates adoption of the official Dutch COVID-19 CTA to gain insight into whether, when, and how resistance influences technology adoption over the course of the technology implementation process. The Dutch CTA tracks contact with other app users via bluetooth and gives recommendations for preventive behaviors and notifications about dealing with contagion upon contact with a user who was diagnosed with COVID-19. It is intended for nation-wide use. Technology acceptance models as well as theories of resistance to behavior change focus on momentary relationships; the current study incorporates the fact that the implementation process is shaped by passing time. Moreover, the individual decision to use a CTA becomes more valuable when others use it as well, indicating the need for insight in the effects of perceived spread of adoption through one's social environment. Previous studies have shown that social norms, i.e., the appropriate behaviour in one's social group, may play an important role in technology acceptance in general (Cialdini & Goldstein, 2004; Venkatesh et al., 2003), and have been related to higher COVID-19 CTA adoption intention and behavior (Fox et al., 2021; Sharma et al., 2020; Tomczyk et al., 2021). Therefore, we investigate resistance to CTA adoption based on anxiety and freedom threat reactions 1) over a longer time period, and 2) in a social context.

The present study contributes to technology acceptance theory and innovation adoption models. Firstly, the longitudinal approach enriches static technology and innovation acceptance models. Researchers have called for studying technology adoption behaviour as a process in longitudinal studies (Venkatesh et al., 2016), shifting toward incorporating discontinuance besides initial adoption in theoretical models (Recker, 2016). The case of CTA use is a realistic application of this process: users can delay using the app or stop and re-start using it at any time. Thus, app adoption is considered here as a dynamic variable that is measured at multiple timepoints, to reach more precise explanations for different phases in the implementation process. Secondly, the present study explores in what way social norms can be integrated in resistance to technology adoption, drawing on behaviour change literature. By investigating the interplay between social norms and the development of psychological resistance processes, it refines and updates the explanations of innovation adoption (e.g. Joachim et al., 2018) and technology acceptance (e.g. Venkatesh et al., 2003).

The present study additionally contributes to social influence theory development and answers to the call to validate norm effects on freedom threat and on behavior in field research (Kavvouris et al., 2020). The natural development pattern of reactance over time provides insight in the nature of reactance, e.g. a defense mechanism that initially spikes when confronted with external pressure to adopt the CTA, or a process that continues outside a direct response to safeguard autonomy (Reiss et al., 2021). Besides, knowledge on the dynamics of this general psychological reaction to persuasion is useful for the content and timing of implementation strategies of any new information system or technology.

1.1. *Theoretical framework*

1.1.1. *Anxiety, time, and social norms*

Apprehension or anxiety is a common aversive reaction to new technologies (e.g., computer anxiety, Simonson et al., 1987; technology anxiety for mobile services, Yang & Forney, 2013). The state of anxiety is a subjective experience of uncertainty resulting from a behavioral conflict (Hirsh et al., 2012) about continuing with the familiar solution or using the new technology. This conflict can occur because innovation initially disrupts the predictable status-quo that people generally want to maintain (Samuelson & Zeckhauser, 1988). By disturbing the need for predictability and structure, the perceived risks of a novel technology pose a barrier to its adoption (Laukkanen, 2016; Talke & Heidenreich, 2014). Next, if it remains unclear whether the innovation, in this case the new technology, is a potential source of reward or threat, and the individual is not confident about dealing with it, fearful responses become the most likely (McNaughton & Corr, 2008). This may lead to rejection of the technology; anxiety of new technology has been related to negative opinions and intentions not to use new smart services (Mani & Chouk, 2018).

Since anxiety is stronger to the extent that an innovation is more radical or unexpected (Müller et al., 2012), it is expected to fade away over time. Gradual exposure to the new technology as it becomes more visible, and its use becomes more common in daily life, would lead to lower levels of anxiety. Thereby, with time, people may overcome their anxiety and become more likely to adopt the new technology. However, this process of change over time has, to the best of our knowledge, not been empirically charted throughout a technology implementation process.

Complementing the soothing effect of the passing of time, a supportive social context may mitigate anxiety, or anxiety may boost norm effects on technology adoption. As a first option, being exposed to people who approve of or adopt the technology may reassure the individual, taking away doubts about the risks (Keck et al., 2014) and thereby reducing anxiety. In this way, the positive effects of supportive norms on technology adoption (Fox et al., 2021; Sharma et al., 2020; Tomczyk et al., 2021) may be mediated by reduced anxiety. As a second option, individuals who find themselves in a state of anxiety may be more likely than confident individuals to follow the social norm, using social support as an external source of control, security and confidence. Indeed, people who experienced threats to personal control became more likely to conform to the social norm (Fritsche et al., 2013), and a sense of fear drove people to base consumption patterns based on the social norm (as measured during the COVID-19 pandemic in China; Li et al., 2021). Applied to technology adoption, if individuals have the idea that the norm is to use the new technology, those in a state of anxiety may more easily conform to the norm to counter their uncertainty (thereby forming a late majority in adoption of the innovation; Rogers, 2003). Thus, effects of social norms may also be moderated by anxiety, so that norm effects are stronger for more anxious individuals. Since there is no empirical consensus on the mediating or moderating process for technology adoption, both processes will be modelled in the current study.

1.1.2. *Reactance, time, and social norms*

The introduction campaign or advertisements intended to persuade people to adopt the new technology may also lead to reactance. Psychological Reactance Theory (PRT; Brehm, 1966; Miron & Brehm, 2006) describes how persuasive efforts in general elicit this form of resistance. Individuals want and expect to have autonomy over their choices. As such, urgent requests to change one's behavior or thoughts can be perceived as threats to personal freedom on how to behave and think, leading to reactance, a motivational state to deal with the threat and regain this freedom (Dillard & Shen, 2005). Reactance is characterized by anger and counterarguing (Rains, 2013), and may result in reactance striving in the form of behavior opposite to what was requested (Mühlberger et al., 2020). Experiments testing this process have mostly focused on outcomes measured at one timepoint or in response to a specific (short-term) event, like a commercial (e.g., Clayton et al., 2018; Miller et al., 2007). In the case of the introduction of CTAs, analyses of Twitter conversations about the COVID-19 CTA in the UK indicated that reactance was a present response (Lavorgna et al., 2021). However, quantitative data about relationships to behavior are lacking, and the time dynamic of reactance in response to new (e-health) technology introductions remains unknown. Thus, insight into longer-term developments of reactance is needed.

The fluctuation of reactance over time has been studied with a focus on short term developments but not on reactions to a continued threat. For instance, experiments have investigated the cardio-vascular responses within minutes when being exposed to the freedom threat or when answering questions (Clayton et al., 2018; Sittenthaler et al., 2015; Spelt et al., 2019). Silvia (2006) showed that sustained freedom threat effects differed dependent on whether participants based their initial disagreement with a message directly on the freedom threat, or on counterarguing following the freedom threat. Only in the latter case, disagreement was maintained after some filler tasks (Silvia, 2006). This suggests that reactance striving may remain active once freedom threat has triggered reactance. Thus, reactance might, in contrast to anxiety, remain a negative predictor of technology adoption over time, although there are no empirical data yet supporting stability or fluctuations in reactance and its effects on behavior over a longer period.

Looking at the context in which reactance develops, existing research demonstrates a multi-faceted relationship between social norms and reactance. The possibility that social norms influence reactance is illustrated in research to pro-environmental behavior, in which freedom threat and counterarguing mediated effects of normative appeals on behavioral intentions (Kavvouris et al., 2020). However, this research did not indicate a uniform effect of all normative appeals on reactance. Specifically, descriptive norms, which describe actual behavior, reduced reactance, whereas injunctive norms, which prescribe the correct behavior, increased reactance. The latter finding is in line with the controlling character of injunctive norms (i.e., "you should"), especially if communicated as part of the persuasive attempt. Like the environmental appeals, injunctive norms for technology adoption might elicit freedom threat, thereby increasing resistance, and descriptive norms may have the opposite effect. However, injunctive norms have been positively directly related to CTA adoption (Tomczyk et al., 2021), which would not suggest increased reactance. An alternative interaction between resistance and social norms follows from the unified theory of acceptance and use of technology (UTAUT; Venkatesh et al., 2003), which states that concerns about autonomy are not altered by the social context, but moderate the effect of social influence on technology use. Specifically, only in mandatory contexts, people were more likely to follow the norm to use technology (Venkatesh et al., 2003). Freedom limitation is not equal to freedom threat, but based on this theory, reactance may strengthen adherence to the social norm. Similar to the potentially entangled effects of social norms and anxiety, the way in which perceived norms interact with reactance and subsequent technology use remains unclear.

1.2. The current research

The current study aimed to address the above-named research gaps concerning anxiety and reactance as resistance to technology acceptance. Thereby, it is the first to examine resistance to the implementation of a CTA over a longer time period, and to integrate the role of perceived social norms in this process. The present study measured reported adoption at four timepoints over the course of four months starting one month after launch, and addresses four research questions.

The first two questions focus on the development of resistance to the implementation of a CTA. Research question 1 was posited to confirm PRT by testing whether PRT predicts reactions to CTA implementation over time in the sequence of freedom threat, reactance and behavior (Brehm, 1966). Specifically, research question 1a stated: Does initially experienced freedom threat relate to increased reactance? Research question 1b followed with: Do anger and counterarguing partly mediate the negative relationship between freedom threat and CTA adoption? In this way, the two facets of reactance, i.e., angry feelings and counterarguing, are tested as separate contributions to behavioural consequences (Rains, 2013). Secondly, it was aimed to explore the unfolding of resistance to the introduction of new technology. Research question 2 states: How do reactance and anxiety towards CTA adoption develop over time?

Furthermore, this longitudinal design integrated contextual influences on resistance to CTA adoption. Therefore, the current study aimed to explore the role of reactance and anxiety in the context of social cues, while also confirming social norms theory. This was targeted in research question 3: Is CTA adoption negatively predicted by (i) reactance and (ii) anxiety, and positively by (iii) descriptive and (iv) injunctive social norms at each timepoint? Finally, resistance was explored in relation to the positive norm effects on CTA adoption over time. Specifically, research question 4 stated: Do anxiety and reactance moderate or mediate the effect[1] of descriptive and injunctive norms on contact tracing app adoption?

We aimed for ecologically valid conclusions by collecting field data from a representative sample of the Dutch adult population, focussing within this sample on the people who would be eligible to use the app (e.g., can use a smartphone). Furthermore, to optimize robustness of the results, analyses of momentary relationships were repeated across all timepoints to replicate them, and analyses involving relationships across timepoints were tested with repeated samples using bootstrapping for maximal robustness of the parameter estimates (Davison & Hinkley, 1997).

2. Method

2.1. Participants

After exclusion, 1480 participants completed the questionnaire at T0, 798 women (53.52%) and 682 men with a mean age of 49.9 (SD = 17.5). At T1, the sample consisted of 1263 participants (676 women (53.52%), with a mean age of 51.3, SD = 17.6). At T2, 1183 participants were included (637 women (53.84%), with a mean age of 52.4, SD = 17.6), and at T3, 1120, with 597 (53.30%) women and a mean age of 52.7 (SD = 17.3).

2.2. Sampling procedures

Participants were an a-select sample invited from the Dutch LISS survey panel (LISSdata.nl), with members based on a true probability sample of households drawn from the Dutch population register by Statistics Netherlands. Participants were recruited for the panel by mail or home visits, and received the necessary means for internet connection in case they did not have that at home. The invited sample consisted of people of 16 years or older, who had completed paid LISS questionnaires on health and the coronavirus at the end of 2019 and start of 2020 (CentERdata, 2021). Participants also received money for participation in all four measurements, which are numbered here from Time 0 to Time 3 (resp., T0, T1, T2, T3).

In order to only investigate the motivations of people who would be able to work with the CTA, excluding technical barriers, participants were excluded per measurement if they did not have a phone, did not have sufficient (technical) knowledge to use the app, did not know how to install apps or how to switch on Bluetooth, or indicated they were not capable of using the app (all scores of 'completely disagree' on these positively phrased statements about eligibility). Participants who indicated they were 'not familiar' with the app before the questionnaire were excluded from the concerning wave because they could not report on their experience about it. With these exclusion criteria applied, the

[1] The word "effect" as used in the research questions, analyses and results is meant to clarify the direction of a relationship between variables as tested in the statistical analyses. It does not define a causal effect, as the present study was not experimental.

data did not contain contradictory answers (like participants indicating they received notifications whilst claiming that they could not install the app).

As common for field data, data were compared between the sample that completed all questionnaires and the sample that had missing data. Missing data only occurred when a participant was not included in a data collection wave; no data was missing on separate variables as all questions required a response. The likelihood of completing all questionnaires was related to CTA use, as participants who did not use the app were more likely to miss data at one point (χ^2 (1) = 38.47, $p < .001$), and participants who missed at least one questionnaire also scored higher on average on the measures of resistance (independent samples *t*-test for anxiety: $t = -4.46$, $p < .001$; and for reactance: $t = -4.99$, $p < .001$). Even though the resistance itself could be a reason for drop-out; whether the data is missing at random or not at random is not a testable assumption. The attrition pattern is potentially influential in particular for the analysis of the fluctuation of resistance over time (RQ2). To exclude the possibility that any pattern is caused by biased selection in later waves, this question was tested using complete case analyses, as one of the recommendations for longitudinal data by Gad and Abdelkhalek (2017). In the other analyses, as many of the existing data as possible are used without creating data that may introduce additional biases (following Gad & Abdelkhalek, 2017, and Hayes, 2017).

2.3. Materials

Brief measures were used to minimize study requirements and thereby attrition. Measures were based on existing validated scales, and adapted to suit the current study's topic, to specifically address experiences related to the Dutch CTA. All items except app use were statements with which agreement was indicated on a seven-point Likert scale ranging from 1 (*completely disagree*) to 7 (*completely agree*).

2.3.1. App adoption

Self-reported use of the CTA was measured at all four timepoints by the item "What is your situation?", with answer options "I use the CoronaMelder app at this moment", "I have used the CoronaMelder app in the past but not anymore at this moment", and "I have never used the CoronaMelder app". "CoronaMelder" is the name of the CTA and is Dutch for corona detector.

2.3.2. Perceived descriptive social norms

The perception of descriptive norms to use the app was measured at all timepoints. Descriptive norms were measured by the item "Many people in my direct environment use the CoronaMelder app".

2.3.3. Perceived injunctive social norms

Perceived injunctive norms were measured at all timepoints by the item "Many people in my direct environment think I should use the CoronaMelder app".

2.3.4. Freedom threat

Perception of freedom threat was measured at T1, T2 and T3 by the item "I do not feel free to choose myself whether to use the CoronaMelder app", operationalizing freedom threat as the subjectively experienced threat to this decisional freedom (Ratcliff, 2019).

2.3.5. Reactance

Reactance was measured at T1, T2 and T3 by 3 items indicating its two characteristics, anger and counterarguing. Anger was composed of the mean of 2 items based on the scale by Dillard and Shen (2005), i.e., irritation and anger. The items read "I am irritated about being pushed to use the CoronaMelder app" and "I am angry about being pushed to use the CoronaMelder app". Anger as a scale had good reliability on all three measurements (T1: Cronbach's $\alpha = 0.90$; T2: $\alpha = 0.91$; T3: $\alpha = 0.89$). Counterarguing was measured by the item "Using the CoronaMelder app has personal disadvantages for me". This operationalization broadly assesses unfavorable cognitions (Rains, 2013) about the app.

Reactance scores were composed by the mean of anger (composite score) and counterarguing, and reliability was around the acceptable level (T1: Cronbach's $\alpha = 0.58$; T2: $\alpha = 0.61$; T3: $\alpha = 0.48$). Anger and counterarguing were positively related at all measures (resp. Spearman's $rho = 0.41$, $rho = 0.45$, $rho = 0.33$, all $ps < .001$), so following the theory of reactance as unitary construct (e.g., Rains, 2013), reactance was included as one variable [2] except for testing research question 1b, which specifically addressed the individual contribution of anger and counterarguing.

2.3.6. Anxiety

Experienced anxiety of the CTA was measured by the item "I think the CoronaMelder app is scary" at T1, T2 and T3.

2.4. Data collection

The present study was conducted in accordance with the Dutch ethical regulations and was independently evaluated and approved by the local ethics committees at the researchers' host institutes, Tilburg University ("Research Ethics and Data Management Committee of Tilburg School of Humanities and Digital Sciences", REDC #2020/133a) and Radboud University (Ethics Committee of the Faculty of Social Sciences, #ECSS-2020-175), The Netherlands.

Data collection took place between October 2020 and March 2021 (see Fig. 1). The studied items were administered in the order described above and were part of larger questionnaires that included items about using the CTA, and adherence to notifications from the CTA as well as to general COVID-19 measures (see: Van der Waal et al., 2021). Each questionnaire took around 10 min to complete.

2.5. Analyses

This is, to the best of our knowledge, the first study to address the current research questions in a longitudinal framework. Therefore, the approach was exploratory, and we accordingly did not create a preregistration but provide the complete analysis script on the Open Science Framework (). The data will become available after the predetermined embargo ends on CentERdata's LISS data archive (https://www.dataarchive.lissdata.nl). The general analysis approach was to replicate analyses across timepoints where possible, and to use bootstrapped confidence intervals for the main analyses where possible. Significance was tested against 95% confidence intervals (CIs), and $\alpha = 0.05$ for simple correlations. All analyses were conducted in R (version 4.1.1, R Core Team, 2021), and are described per research question.

2.5.1. Research question 1a. Does initially experienced freedom threat lead to higher reactance?

First, to assess the relationship between freedom threat at T1 and reactance at T1, T2 and T3, two-sided pairwise Spearman correlations (to obtain estimates for skewed distributions, package "stats"; R Core

[2] To check whether using anger and counterarguing as separate variables in the hypothesis tests would lead to similar conclusions, all statistical models that involved reactance have been repeated with reactance replaced by anger and counterarguing. All results followed the same significance pattern, with one exception for the time dynamic of reactance, where a significant gradual decrease in anger was observed (for the complete cases from $M = 3.00$ ($SD = 1.58$) at T1 to $M = 2.86$ (1.53) at T2, and $M = 2.88$ (1.51) at T3, but this decrease was not significant in counterarguing (at T1: $M = 3.09$ ($SD = 1.72$), T2: $M = 2.96$ (1.66), T3: $M = 3.05$ (1.68)). In all other models, both anger and counterarguing had the same significant effects as reactance, as reported in the Results section.

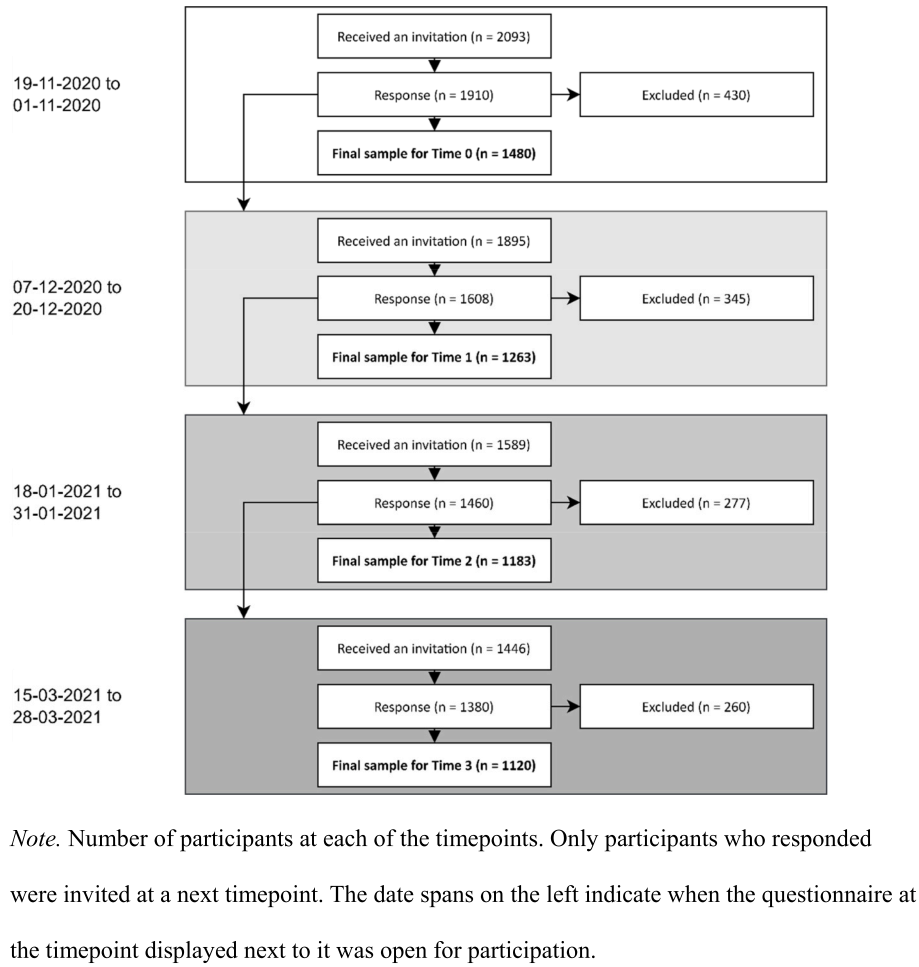


Fig. 1. Participant Flow in the Present Study
Note. Number of participants at each of the timepoints. Only participants who responded were invited at a next timepoint. The date spans on the left indicate when the questionnaire at the timepoint displayed next to it was open for participation.

Team, 2021) were obtained of freedom threat scores at T1 and reactance at T1, T2 and T3. Second, to investigate the effect of freedom threat at T1 on reactance over time, a linear mixed effects model was conducted with reactance scores predicted by freedom threat at T1, time (3 levels, T1, T2, T3), and the interaction between freedom threat and time as fixed effects, with a random slope for time per participant plus a random intercept per participant, using the package "lme4" (Bates et al., 2015). The predictor scores were centered, and parametric bootstrapped CIs were obtained with 10,000 samples using the "lme4" and "boot" packages (Canty & Ripley, 2021; Davison & Hinkley, 1997).

2.5.2. Research question 1b. Do anger and counterarguments both partly mediate the negative relationship between freedom threat and CTA use?

A mediation analysis was conducted to investigate this process between measured variables. To benefit from mediation analyses in a longitudinal study design, this was performed with mediators measured at the next timepoint after the predictor, and the outcome measured at the next timepoint after the mediators (Hayes, 2017). The analysis was performed using PROCESS (PROCESS version 4.0.1 in R, Hayes, 2017), model 4, with freedom threat at T1 as predictor, anger and counterarguments at T2 as parallel mediators, and CTA use at T3 as outcome. All continuous variables were centered, bias-corrected bootstrapped CIs were obtained based on 10,000 bootstrap samples, and cases with missing data were automatically deleted.

2.5.3. Research question 2. How do anxiety and reactance towards CTA adoption develop over time after launch?

This question was tested using complete cases to avoid possible confounding effects of attrition. Two mixed-effect model analyses were conducted with reactance and anxiety as respective outcome variables, using the package "lme4". Time was added as polynomial fixed effect, to be able to assess not only linear patterns, but also quadratic, and in case of anxiety, cubic, changes over time. The function poly() (from the package "stats"; R Core Team, 2021) was used to create orthogonal polynomials to prevent correlation issues between the polynomial terms. The model predicting anxiety covered 4 timepoints, and thus included first, second and third degree polynomials. The model predicting reactance covered 3 timepoints and thus included polynomials of the first and second degree. Both models included a random slope for time per participant and a random intercept per participant. CIs were obtained from 10.000 bootstrapping samples using the package "boot".

Two additional patterns were analyzed to aid interpretation of the developmental models. To explore whether the two forms of resistance were related, two-sided Spearman correlations were computed for anxiety and reactance at T1, T2 and T3. To explore whether resistance at one point was related to resistance at the next timepoint within participants, two-sided Spearman correlations were computed for anxiety between T0 and T1, and for reactance and anxiety between T1 and T2 and T2 and T3.

2.5.4. Research question 3. Is CTA adoption at each measurement negatively predicted by reactance and anxiety, and positively by descriptive and injunctive social norms?

This question was tested by logistic regression analyses of CTA use for each timepoint to determine the effects for T0 to T3 separately. For each timepoint, the predictors were anxiety, reactance (from T1 onward), descriptive norms, and injunctive norms, all from the same timepoint and all grand-mean centered (Toothaker et al., 1994). The models included all interaction terms (i.e. full models) to include variance of possible interactions. Bootstrapped CIs were obtained with 1000 samples using the "lme4" and "boot" package.

2.5.5. Research question 4. Do anxiety and reactance moderate or mediate the effect of descriptive and injunctive norms on contact tracing app adoption?

Hereby, the analyses shift from interactions at one timepoint to the exploration of norms and resistance across timepoints. Moderation and mediation were both investigated. To test moderation, two different moderation models were tested using PROCESS model 2 (Hayes, 2017), one with descriptive and one with injunctive norms as predictor. In both models, CTA use was the outcome, estimated by logistic regression, and reactance and anxiety were entered as parallel *moderators*. To test mediation, two different mediation models were tested using PROCESS model 4 (Hayes, 2017), again one with descriptive norms and one with injunctive norms as predictor, CTA use as outcome, and reactance and anxiety this time as parallel *mediators*.

For robustness, all these models were tested in two series of consecutive measurements, i.e.: norms (predictor) measured at T0, resistance (moderators resp. mediators) at T1, and CTA use (outcome) at T2; and norms at T1, resistance at T2, and CTA use at T3. In all analyses, the continuous variables were centered, bias-corrected bootstrapped CIs were obtained based on 10,000 samples, and cases with missing data were automatically deleted.

3. Results

3.1. Participant flow

In total, data collection resulted in $N = 943$ complete cases. See Fig. 1 for an overview of the participant flow.

3.2. Descriptives

Means and standard deviations of all measured variables, as well as CTA use rates, are reported per timepoint in Table 1.

3.3. Research question 1a. Does freedom threat positively predict reactance, also later on?

The correlations between freedom threat at T1 and reactance at T1, T2 and T3, were all weakly positive and significant (respectively, T1: Spearman's $rho = 0.25$, $p < .001$; T2: $rho = 0.23$, $p < .001$; T3: $rho = 0.22$, $p < .001$). This indicates that people who experienced more freedom threat at the first timepoint experienced more reactance at that time, but also up to four months later.

Table 1
Means and Standard Deviations of Resistance, Social Norms, and % CTA use.

Variable	Descriptives, *M* (*SD*)			
	T0: n = 1480	T1: n = 1263	T2: n = 1183	T3: n = 1120
Freedom threat		2.57 (1.59)	2.49 (1.50)	2.39 (1.48)
Reactance		3.16 (1.41)	3.05 (1.40)	3.05 (1.30)
Anxiety	2.86 (1.66)	2.49 (1.52)	2.39 (1.46)	2.32 (1.41)
Descriptive norms	3.56 (1.43)	3.50 (1.51)	3.43 (1.57)	3.37 (1.55)
Injunctive norms	3.34 (1.54)	3.11 (1.61)	3.12 (1.62)	2.95 (1.58)
CTA use (%)	34.05%	39.11%	38.80%	38.57%

Note. Scores on a Likert scale from 1 to 7.

In line with this, the effect of freedom threat at T1 on reactance in the linear mixed effects model was positive and significant (*Estimate* = 0.20, *SE* = 0.02, 95% CI [0.16; 0.24]), indicating that the experience of higher freedom threat at the first measurement was related to higher reactance throughout the measurements. There was a significant negative effect of time on reactance (*Estimate* = −0.05, *SE* = 0.02, CI [−0.08; 0.02]), indicating a structural decrease in reactance over time in this linear model. The interaction between freedom threat and time was significant as well (*Estimate* = −0.03, *SE* = 0.01, CI [−0.05; −0.01]). This means that the positive relationship between freedom threat T1 and reactance became a bit weaker over time, from when reactance was measured at the same moment to four months later.

3.4. Research question 1b. Do anger and counterarguments mediate the negative effect of freedom threat on CTA adoption?

The overall mediation model of 1010 complete cases on T1 to T3 significantly predicted both mediators, anger ($R^2 = 0.06$, $F(1, 1008) = 69.80$, $p < .001$) and counterarguing ($R^2 = 0.02$, $F(1, 1008) = 22.06$, $p < .001$) at T2, as well as the outcome, CTA use at T3 (Nagelkerke's $R_N^2 = 0.32$, $p < .001$). Specifically, freedom threat increased both anger ($B = 0.25$, $SE = 0.03$, 95% CI [0.18; 0.31]) and counterarguing ($B = 0.15$, $SE = 0.03$, CI [0.08; 0.22]). In turn, anger ($OR = 0.60$, 95% CI [0.52; 0.67]) and counterarguing ($OR = 0.61$, CI [0.55; 0.68]) both reduced the likelihood of adopting the CTA.

The indirect effects indicated that the influence of freedom threat at T1 on later CTA use was significantly partly mediated by anger ($OR = 0.88$, 95% CI [0.84; 0.92]) as well as counterarguing ($OR = 0.93$, CI [0.89; 0.96]). Thus, if participants experienced more freedom threat, they also reported higher anger and counterarguing, which related to being less likely to use the CTA.

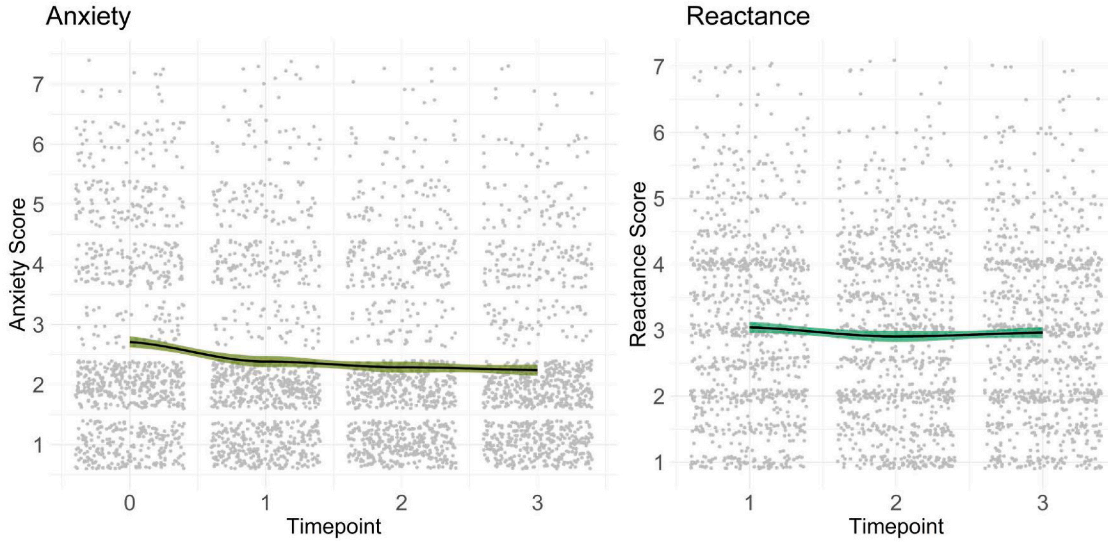
3.5. Research question 2. How do reactance and anxiety towards CTA adoption develop over time after launch?

Over time, the mean reactance of participants with complete data varied between 3.05 and 2.97 on a scale from 1 to 7, which translated in an overall significant negative linear time effect (*Estimate of first order polynomial* = −1.75, *SE* = 0.74, 95% CI [−3.20; −0.31], with a random slope of time *SD* = 0.12). The quadratic time effect was significantly positive (*Estimate of second order polynomial* = 2.43, *SE* = 0.70, 95% CI [1.05; 3.80]), reflecting the reduction in reactance at first and stability later on, see Fig. 2.

The change in anxiety that appeared in the complete cases' mean scores, from 2.71 to 2.24, concurred with a significant and negative linear effect of time (*Estimate of first order polynomial* = −10.33, *SE* = 1.04, 95% CI [−12.36; −8.31]), see Fig. 2. The quadratic effect of time was positive and significant (*Estimate of second order polynomial* = 4.28, *SE* = 0.93, 95% CI [2.47; 6.13]), indicating that the decrease in anxiety was sharper at first and became flatter later on. The cubic effect of time was not significant (*Estimate of third order polynomial* = −1.26, *SE* = 0.93, 95% CI [−3.10; 0.52]), indicating that there were no structural extra fluctuations in the development of anxiety.

Spearman correlations between anxiety and reactance per timepoint showed that participants who felt more anxious on average also experienced stronger reactance. The correlations were significantly positive and of moderate strength (T1: $r = 0.53$; T2: $r = 0.50$; T3: $r = 0.47$, all *ps* $< .001$).

The Spearman correlations over time indicated consistently that participant's levels of resistance were significantly and positively correlated across timepoints, with strong correlations for both reactance and anxiety, see Table 2. This shows that the observed trends over time are largely similar throughout the participant sample.



Note. Reported anxiety (left) and reactance (right) towards the contact tracing application. Timepoint 0 represents the measurement 1 month after the introduction of the contact tracing app, Timepoint 1 was measured approximately 1 month later, Timepoint 2 again roughly 1 month later, and Timepoint 3 roughly 2 months after that. Reactance was not measured at Timepoint 0. Each grey dot represents a datapoint. The black line is a smoothed loess line through the mean scores. The green bands around the lines represent 95% confidence intervals.

Fig. 2. Development of Anxiety and Reactance over Time
Note. Reported anxiety (left) and reactance (right) towards the contact tracing application. Timepoint 0 represents the measurement 1 month after the introduction of the contact tracing app, Timepoint 1 was measured approximately 1 month later, Timepoint 2 again roughly 1 month later, and Timepoint 3 roughly 2 months after that. Reactance was not measured at Timepoint 0. Each grey dot represents a datapoint. The black line is a smoothed loess line through the mean scores. The green bands around the lines represent 95% confidence intervals.

Table 2
Bivariate Correlations between Timepoints for Anxiety and Reactance.

Variable	T0-T1	T1-T2	T2-T3
Reactance		$r = .73$	$r = .72$
Anxiety	$r = .56$	$r = .68$	$r = .56$

Note. Reactance was not measured at T0. r = Spearman's rho. All correlations were significant at $p < .001$.

3.6. *Research question 3. A is CTA adoption at each timepoint negatively predicted by reactance and anxiety, and positively by descriptive and injunctive social norms?*

At T0, the logistic regression analysis showed that CTA use was significantly predicted by anxiety, descriptive norms and injunctive norms. Stronger anxiety was related to a lower likelihood of CTA use (*OR* = 0.50, 95% CI [0.44; 0.56]). In contrast, stronger perceived descriptive (*OR* = 1.82, 95% CI [1.53; 2.16]) as well as injunctive (*OR* = 1.67, 95% CI [1.44; 1.94]) norms were related to a higher likelihood of CTA use. None of the interactions were significant (i.e., all CIs included 1 in the interval). Thus, at T1, CTA use was more likely for participants with less anxiety and stronger perceived positive norms.

At T1, CTA use was again significantly predicted by anxiety, descriptive and injunctive norms, and also by reactance. Specifically, reactance (*OR* = 0.38, 95% CI [0.29; 0.44]) and anxiety (*OR* = 0.71, 95% CI [0.58; 0.83]) predicted CTA use negatively. In contrast, perceived descriptive (*OR* = 2.13, 95% CI [1.80; 2.74]) and injunctive (*OR* = 1.58, 95% CI [1.36; 1.96]) norms to use the app predicted CTA use positively. None of the interactions were significant. Thus, at T2, CTA use was less likely to the extent that participants scored higher on reactance and more likely to the extent that they scored higher on perceived norms to use the app.

The analysis at T2 showed the same general pattern of results. The fitting of the full model led to convergence issues yielding unrealistic *OR*s of around 500 and approaching 0 that were not solved by adding optimizers or scaling the variables. To be able to test the effects of interest, the model was simplified by excluding the random intercept per participant, which solved the issue. CIs for this model were obtained with 10,000 bootstrapping samples and showed that reactance (*OR* = 0.32, 95% CI [0.24; 0.39]) and anxiety (*OR* = 0.61, 95% CI [0.49; 0.73]) negatively predicted CTA use; whereas descriptive (*OR* = 2.08, 95% CI [1.73; 2.69]) and injunctive (*OR* = 2.54, 95% CI [2.17; 3.25]) norms positively predicted CTA use. The interaction between descriptive and injunctive norms was significantly negative ($OR = 0.85$, 95% CI [0.76; 0.97]), indicating that once the one type of norms was perceived, the other became less influential. None of the other interactions were significant.

The analysis at T3 followed this main-effects pattern as well. Reactance ($OR = 0.32$, 95% CI [0.24; 0.40]) and anxiety ($OR = 0.66$, 95% CI [0.49; 0.80]) negatively predicted CTA use; whereas descriptive ($OR =$ 2.42, 95% CI [2.03; 3.22]) and injunctive ($OR = 1.98$, 95% CI [1.67; 2.57]) norms positively predicted CTA use. None of the interactions were significant.

To summarize these logistic regression analyses, at all timepoints, reactance and anxiety were related to a lower likelihood of CTA use, and descriptive as well as injunctive norms were related to a higher likelihood of CTA use.

3.7. Research question 4. Do anxiety and reactance moderate or mediate the effect of descriptive and injunctive norms on CTA use?

3.7.1. Moderation

To shift from predicting CTA use within one timepoint to predictions across time, moderation analyses were conducted to assess the interaction between norms and resistance in subsequent timepoints. The moderation analyses that tested the effects of *descriptive* norms on CTA use, indicated no significant moderation of either reactance of anxiety. The model testing consecutive measures of T0, T1 and T2 ($n = 1018$, Nagelkerke's $R^2_N = 0.49$, $p < .001$) showed that descriptive norms positively affected CTA use, reactance and anxiety negatively affected CTA use, but there was no interaction between norms and reactance or anxiety, see Table 3. The model testing measures of T1, T2 and T3 followed the same result pattern ($n = 1010$, Nagelkerke's $R^2_N = 0.50$, $p <$ .001), see Table 3.

The moderation analyses that tested the effects of *injunctive* norms on CTA use indicated no significant moderation of reactance or anxiety either. The model testing consecutive measures of T0, T1 and T2 ($n =$ 1018, Nagelkerke's $R^2_N = 0.49$, $p < .001$) yielded a positive effect of injunctive norms on CTA use, and again a negative effect of reactance and anxiety on CTA use. The interaction was not significant, see Table 3. The model testing measures of T1, T2 and T3 ($n = 1010$, Nagelkerke's $R^2_N = 0.48$, $p < .001$) showed the same pattern, see Table 3.

Table 3
Effects of the Moderation Analyses of Research Question 4.

	Moderation Analyses				
	Variable	Effect on App Use at T2		Effect on App Use at T3	
		OR	95% CI	OR	95% CI
Analyses with Descriptive Norms	Descriptive Norms	1.91*	1.65; 2.22	2.29	1.96; 2.66
	Reactance	0.42*	0.36; 0.50	0.47	0.40; 0.55
	Anxiety	0.80*	0.70; 0.92	0.81	0.69; 0.94
	Reactance × Norms	1.01	0.88; 1.18	1.07	0.93; 1.25
	Anxiety × Norms	0.94	0.84; 1.06	0.98	0.86; 1.12
Analyses with Injunctive Norms	Injunctive Norms	1.80*	1.58; 2.04	1.98*	1.74; 2.27
	Reactance	0.41*	0.35; 0.49	0.44*	0.38; 0.52
	Anxiety	0.77*	0.66; 0.89	0.77*	0.65; 0.90
	Reactance × Norms	1.03	0.91; 1.17	0.98	0.87; 1.11
	Anxiety × Norms	0.98	0.89; 1.08	1.07	0.95; 1.22

Note. * = significant at 95% CI.

Thus, participants who perceived CTA use as normal or desired in their environment were more likely to use the CTA later on, and participants who experienced reactance or anxiety were less likely to use the CTA later on. However, reactance and anxiety did not reduce the positive effect of norms on CTA use.

3.7.2. Mediation

The mediation analyses that tested the indirect effects of *descriptive* norms on CTA use indicated a significant mediation effect of both reactance and anxiety ($n = 1018$, Nagelkerke's $R^2_N = 0.49$, $p < .001$), see Fig. 3, panel A. The model testing consecutive measures of T0, T1 and T2 showed that descriptive norms positively affected CTA use, whereas reactance and anxiety negatively affected CTA use. Both reactance and anxiety partially mediated the effect of norms on CTA use, see Fig. 3, panel A. The model testing the same variables but measured at T1, T2 and T3 yielded the same results ($n = 1010$, Nagelkerke's $R^2_N = 0.50$, $p <$ .001), see Fig. 3, panel B.

The analyses of perceived *injunctive* norms followed this result pattern. The model testing consecutive measures of T0, T1 and T2 showed that injunctive norms positively affected CTA use, reactance and anxiety negatively affected CTA use, and both reactance and anxiety partially mediated the effect of norms on CTA use ($n = 1018$, Nagelkerke's $R^2_N = 0.49$, $p < .001$), Fig. 3, panel C. The model testing the same model but at the consecutive measures of T1, T2 and T3 yielded similar results ($n = 1010$, Nagelkerke's $R^2_N = 0.48$, $p < .001$), see Fig. 3, panel D. Thus, participants who perceived more CTA use in their social environment at T0 were less likely to experience reactance or anxiety at T1, and thereby became more likely to use the CTA at T2.

* = $p < .05$.

Thus, participants who perceived CTA use as desirable in their social environment were less likely to experience reactance or anxiety, and thereby became more likely to use the CTA.

4. Discussion

This longitudinal study aimed to shed light on the development of resistance to adoption of a CTA, by investigating the relationship between anxiety and reactance toward the introduction of the CTA and CTA use, taking into account temporal dynamics and perceived social norms. In order to do this, participants who would be capable of using this app were followed within a representative Dutch adult sample. In four measurements during the five months after the COVID-19 CTA launch, their resistance throughout the CTA implementation process was explored.

The first research question investigated whether the experience of freedom threat predicted CTA adoption as posited by Psychological Reactance Theory (PRT; Brehm, 1966). It was found that initial experience of freedom threat to one's choice to use the CTA made people more reactant, also after several months had passed. Over time, the emotional and the cognitive components of reactance (anger and counterarguing) combined partly mediated the negative relationship that freedom threat had with app adoption. This dual route to behavior by emotional and cognitive responses is in line with models based on experiments that tested one-time freedom threats (Rains, 2013).

Research question 2 investigated the development of resistance to CTA implementation over time and showed that resistance declined gradually, especially the anxious feelings. This demonstrates how familiarization with new technology can relieve some of the resistance to it, adding to the findings that technology anxiety is a source of rejection of smart services (Mani & Chouk, 2018). The gradual decline in anxiety may reflect the increased exposure to the app with the passing of time. Moreover, the sharper anxiety reduction at first, followed by a slower further reduction, corresponds to the notion that the app's newness instigated the anxious response. This is in line with experiments showing that more radical innovations yield a stronger negative response than more familiar solutions (Müller et al., 2012).

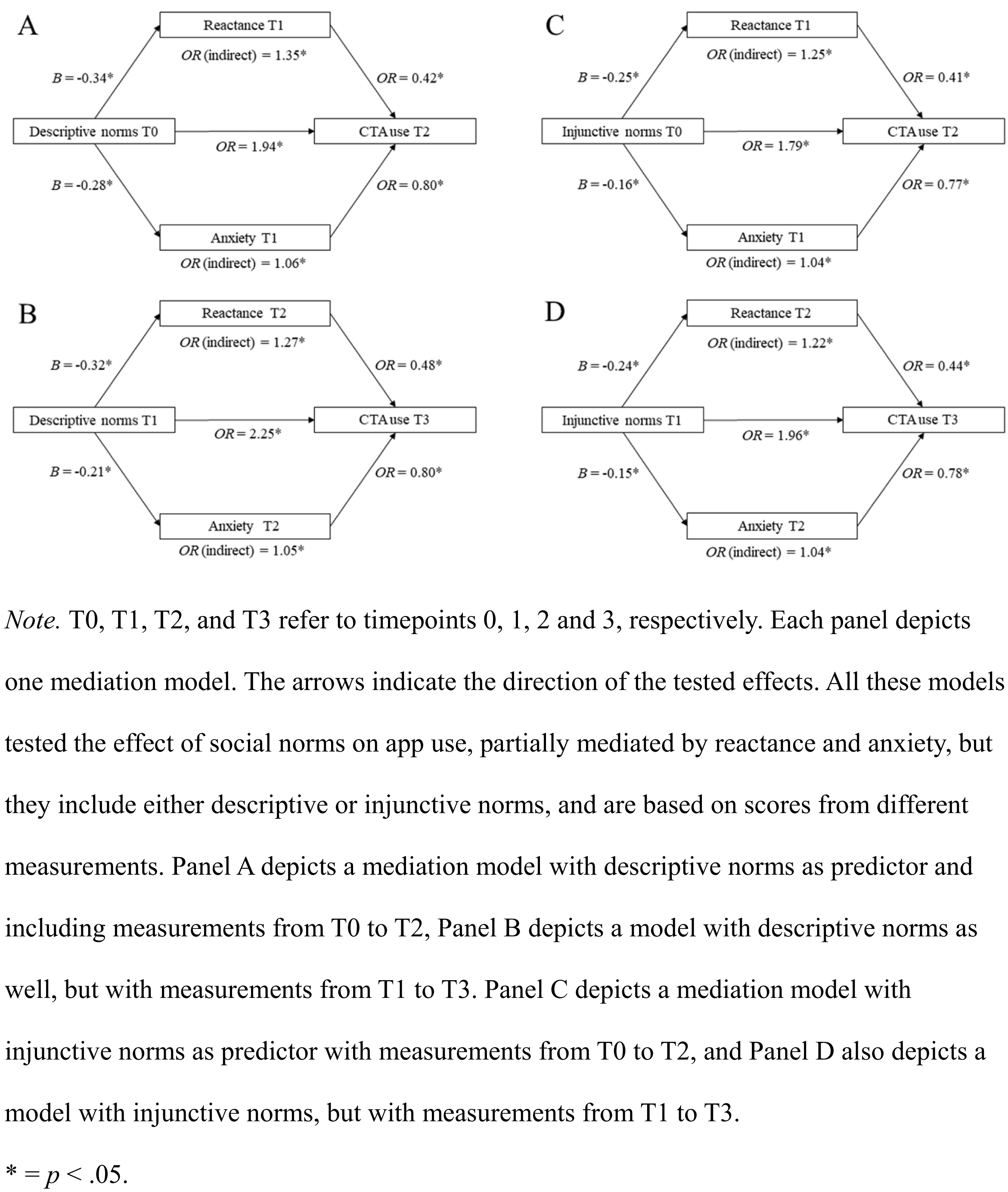


Fig. 3. *Significant Paths in Mediation Models of Research Question 4*
Note. T0, T1, T2, and T3 refer to timepoints 0, 1, 2 and 3, respectively. Each panel depicts one mediation model. The arrows indicate the direction of the tested effects. All these models tested the effect of social norms on app use, partially mediated by reactance and anxiety, but they include either descriptive or injunctive norms, and are based on scores from different measurements. Panel A depicts a mediation model with descriptive norms as predictor and including measurements from T0 to T2, Panel B depicts a model with descriptive norms as well, but with measurements from T1 to T3. Panel C depicts a mediation model with injunctive norms as predictor with measurements from T0 to T2, and Panel D also depicts a model with injunctive norms, but with measurements from T1 to T3.

Besides anxiety, his study is one of the first to chart the fluctuation of reactance toward a new behaviour over time, but rather than revealing substantial oscillations; it showed just a slight decrease. The downward trend may be explained by the simultaneous decrease in anxiety of the CTA, and the positive correlations between anxiety and reactance. Higher anxiety at the beginning indicated that participants saw the CTA as a larger potential threat, making a decision about using it highly personally relevant. For more relevant decisions, reactance is more likely to occur (e.g., Rosenberg & Siegel, 2018), so with decreasing threat and relevance, reactance may have decreased as well.

However, the changes in reactance over the course of several months are rather small, and reflect an average total change of 0.1 point on a seven-point scale. This suggests that the motivation to counter effects of persuasion remains active even after making a (preliminary) decision. A first possible theoretical account for this relative steadiness is that initial experienced freedom threat elicits a vicious circle of processing information about the app. Following the reactance process research by Silvia (2006), and congruent with those short-term findings, initial freedom threat affects the way of processing all evidence not only momentarily, but on the longer term. This may be caused by confirmation bias in the counterarguing response through which people confirm their negative thoughts step by step, indicating a defense motivation (Steindl & Jonas, 2015). A slight variation to this processing bias is provided by the account that freedom threat apparently creates a relatively stable decision ("I'll never use it"), similar to a general negative attitude that is stable over time (Petty & Krosnick, 1995). In line with this idea, this field study revealed that participants did not often change their use of the CTA; the groups of users and non-users remained relatively stable. Moreover, numerous studies have shown how reactance influences attitudes (Silvia, 2006; Spelt et al., 2019).

Alternatively, it seems possible that the relative stability of reactance is due to individual differences in the tendency to experience reactance across situations (trait reactance; Rosenberg & Siegel, 2018). The used measures all focused on momentary reactions to this CTA, but these may have partly been an expression of underlying trait reactance. Innovation adoption models acknowledge this possibility by stating that resistance can be evoked by the context, or a person may be more predisposed to going against change (Talke & Heidenreich, 2014). In line with this, processing bias and early attitude formation remain possible explanations for the current development pattern, and individual differences may have contributed in parallel.

Next to placing resistance to CTA implementation in a time perspective, the current study integrated resistance in the social context. The results of research question 3 showed that at each timepoint, both anxiety and reactance were related to a lower likelihood of using the app, controlling for social normative influences. In contrast, perceived descriptive and injunctive norms favoring CTA use were positively related to app adoption, and did not interact with reactance or anxiety. Research question 4 specified the way in which social norms may affect people's behaviour. That is, the positive relationships of descriptive as well as injunctive norms with app adoption were partly mediated by lower anxiety and reactance about using the app. Concretely, positive norms related to lower resistance later on, which then predicted higher adoption. There was no support for the model in which resistance moderated the relationship of norms with app adoption.

The positive normative predictive effects on CTA adoption confirm research to CTA adoption (Fox et al., 2021; Sharma et al., 2020; Tomczyk et al., 2021) and a large body of technology acceptance literature (e.g., Lee et al., 2013). New to that large body, however, the longitudinal findings tell us that part of the normative boost of technology adoption seems to be due to how norms suppress resistance in the form of anxiety and reactance. This concurs with the idea that positive norms relieve anxiety, anger, and negative thoughts by providing positive exposure to the opposite opinion and behaviours (as shown for descriptive norms relieving reactance by Kavvouris et al., 2020; and for relieving uncertainty avoidance by Keck et al., 2014). In contrast to Kavvouris and colleagues' experiments about normative appeals, even injunctive norms reduced reactance instead of increasing it. This could be due to the fact that norms in the current study were self-perceived instead of induced as appeal, thereby alleviating the experienced manipulativeness.

4.1. Theoretical contributions

The present work contributes to the literature on drivers and barriers of technology adoption, connecting innovation adoption literature, technology acceptance models, and social influence theory. For the first time, it shows the temporal dynamics after launch of psychological resistance to a new CTA, and elaborates on the way in which social norms positively relate to technology adoption. These new insights are valuable for research on mobile apps, contact tracing technology, and e-health in specific, as well as technology adoption in general.

A first and general contribution is that the visible development of anxiety and reactance over time illustrates how technology acceptance and innovation adoption theory can be enriched by including a dynamic perspective. Not only initial (intention of) adoption, but also continued or discontinued app use in the following months is related to resistance. The slowly fluctuating levels of resistance imply that incorporating (dis) continuation enrich static adoption models, by which they become more precise.

Next, the present study highlights the presence of psychological resistance mechanisms in technology adoption, thereby demonstrating that basic psychological reactions can be applied to explain CTA adoption. This suggests that innovation and technology acceptance research would benefit from including reactance and anxiety in their models. This may be applicable to health and tracking technologies besides CTAs, since reactance can be elicited for self-relevant choices (Rosenberg & Siegel, 2018), and concerns about health or privacy indicate direct personal relevance of a technology.

Furthermore, the longitudinal design validates norm effects on freedom threat and behavior in the field. It confirms the established importance of social norms for technology adoption (e.g. Venkatesh et al., 2003). Beyond this, the partial mediation of norm-behavior relationships by reactance and anxiety suggests that norms naturally function to prevent resistance. As noted in social influence literature, norms are followed to gain control (Fritsche et al., 2013), and seeing a clear norm may indeed relieve threat when confronted with new digital solutions. It also gives empirical directions for the place of social norms in models predicting (CTA) technology adoption: as precursor of resistance. Currently, technology and innovation adoption models acknowledge social influence as predictor of acceptance (Joachim et al., 2018; Venkatesh et al., 2003), but do not specify the working mechanisms. Doing so contributes not only to in-depth understanding of the process of technology acceptance, but also to the useablity of models for intervention design.

Finally, the findings advance understanding about resistance to persuasion itself, which is relevant for the commercial introduction of any new digital system. Research into state reactance has explained reactance as direct reaction to a concrete freedom threat (Reiss et al., 2021), but the currently studied situation was different; The continued relationship between reactance and app adoption took place over the course of months, with exposure to more than one influencer and message. The relationships between freedom threat, reactance and behavior in the current study clarify that reactance is not just a direct communication signal to an influencer to grant more autonomy. Instead, the lingering reactance seems to serve as a protection of autonomous decision making, thereby expanding the scope of the freedom threat from specific controlling messages (Reiss et al., 2021) to an enduring freedom threat rooted in a collection of (CTA-campaign) messages of different influencers over time, which will not all be explicitly remembered.

4.2. Societal implications

The present research clearly shows how the implementation of a CTA needs the absence or minimalization of negative affect (anxiety, anger). It thereby implies that efforts to spread a new CTA or other health or tracking technology among the whole (capable) target group needs to focus not only on convincing individuals of the usefulness, ease of use (e.g., UTAUT), or severity of health risks when not using the e-health solution (e.g., Health Belief Model). Instead, it needs monitoring of emotional reactions like anger and anxiety, and of how known predictors relate to these emotional states. The longitudinal data tentatively suggests using both injunctive and descriptive positive norms as a way to reduce resistance and increase CTA adoption, although the causality of this relationship needs additional experimental research. Of course, the effectiveness of induced normative appeals may differ from the effects of spontaneous personal perceptions. This remains to be tested, and thereby illustrates how these findings also incite new applied research.

The results over four months time revealed that preventing freedom threat is not only important for the first response to the new technology, but it remains influential later in the implementation process as well (i.e., for early adopters and laggards alike; Rogers, 2003). A potentially effective technique to prevent reactance would be using self-persuasion – convincing people that motivation comes from within – instead of direct persuasion. Self-persuasion succesfully prevented reactance in adoption of COVID-19 measures (Drążkowski et al., 2020). Given the multiple considerations that are at play in adopting a CTA, such as health and privacy concerns (Chan & Saqib, 2021; Walrave et al., 2020), a combination of multiple interventions is most likely to be successful, as was also suggested by Rehse (2021).

4.3. Generalizability

The implications are generalizable to specific contexts, samples, and technologies. The present study took place in a Western country and culture, where government intrusion is not common and app adoption was voluntary. Hence, without further research, implications should not be generalized outside these situations.

As in most studies with measurements over time, attrition played a role. The aim of the present study was to explore resistance to the CTA in a sample of the population that is capable of using the app. Self-selection in drop-out has tightened this group to people who are willing to report about this. We emphasize that the conclusions hold only for people who are open to and capable of considering the use of a CTA. Accordingly, the results indicate that even a sample showing minimal to moderate resistance demonstrates negative relationships between resistance and app use over multiple months time. The fact that drop-out was more likely for people with higher resistance scores may reflect an established resistance strategy: avoidance of the threat (Fransen et al., 2015). Future research could complement the present findings by investigating strong opponents of a new technology, with methods targeted to keep this sub-sample engaged.

Regarding the technological innovation, the Dutch CTA is considered as example of the introduction of new technologies. It is a special technology in the sense that the personal benefits of using a CTA depend on the adoption of others, and it was designed as a health protection instrument against COVID-19. Similar processes are thus at least to be expected in other new passive (e-health) technologies aimed at dealing with infectious diseases. However, the studied CTA also shares characteristics with other new (mass-use) technologies; its technological specifications were still under development, its pros and cons are debated in public (for instance as examined across countries, Altmann et al., 2020; and in Twitter data, Lavorgna et al., 2021), it was accessible to most people, and did not require intensive or skilled interaction. Thus, if considered with due care, the overall implications are relevant for technology adoption in general.

4.4. Limitations and future directions

The present research also has its specific limitations. Firstly, it focused on two forms of resistance, and did not take place in isolation of potential other influences. For instance, the CTA was introduced in the context of dealing with the COVID-19 pandemic. As with any correlational study, it cannot be ruled out that other individual tendencies play a role (Ye et al., 2021), or that there are contextual influences on the measured variables besides the introduction of the mobile app, such as reactance to vaccination that spilled over to negative intentions for other COVID-19 preventive behaviors (Sprengholz et al., 2021). The measured predictors might have been influenced by other app-related beliefs and concerns, such as privacy, functionality or health concerns; or by reactions to other COVID-19 measures. Conceptualizations were sensitive to experimental manipulations of the constructs, and all questions explicitly focused on the CTA app to prevent this as much as possible. Given the width of potential influential factors that are still being revealed, the present study was explicitly focused on the psychological mechanisms related to the app itself. Future research could investigate what elicits the experience of anxiety and reactance to COVID-19 CTAs and other technology introductions.

Secondly, the brief measures of all constructs enabled us to collect data from a wide sample of participants, but may also have led to less precise results. Reactance easurements started after the first introduction of the CTA, and presence of reactance indicates that it already arose earlier. Thus, the elicitation of this form of resistance cannot be characterized as quick, slow, steadily or abrupt. A more fine-grained temporal measurement schedule may be better able to grasp the start of this process and distinguish state effects from individual traits. This could be paired with automatic measurements of app use to reduce the inevitable noise around self-reported behavior, in order to optimally map expressions of resistance.

Lastly, the present study gives insight in within-person trajectories instead of the causal relationships. To further causally explain the individual developments, testing the suggested vicious circle of freedom threat would be a promising avenue for future research. For instance, by exploring the role of freedom threat memories on reactance, or by disentangling the conditions under which emotional or cognitive facets of reactance influence technology acceptance. Experimental research may also build on the current findings to explain why the relationship between norms and app adoption is mediated by resistance. For instance, social norms might change the threat perception by its informative function (Rimal & Lapinski, 2015). This may be of particular interest to explore in more complex digital innovations.

5. Conclusions

Taken together, the findings highlight and specify the impact of resistance and the social context over the course of the extended implementation process of a CTA. The results concerning research question 1a (Does initially experienced freedom threat relate to increased reactance?) indicated that stronger experienced freedom threat related to stronger reactance at the same measurement and over time. Regarding research question 1b, (Do anger and counterarguing partly mediate the negative relationship between freedom threat and CTA adoption?) results showed that once people experience freedom threat, they were less likely to adopt the app even months later; a process that is partly mediated by anger and counterarguing. The findings of research question 1 thus imply that PRT is reflected in the reaction to the Dutch COVID-19 CTA over time, with both affective and cognitive mechanisms. Results related to research question 2 (How do reactance and anxiety towards CTA adoption develop over time?) showed that reactance and anxiety toward the CTA decreased slightly over the months of the study. Thus, resistance to a COVID-19 related CTA gradually fades during the implementation process, mostly due to softened anxiety. Research question 3 and 4 put resistance in a social context, by incorporating perceived descriptive and injunctive social norms of CTA use. Findings based on research question 3 (Is CTA adoption negatively predicted by reactance and anxiety, and positively by descriptive and injunctive social norms at each timepoint?) show that at all times during the implementation process, the relationship of reactance and anxiety with app adoption was negative, next to the positive relationships of social norms. Results regarding research question 4 (Do anxiety and reactance moderate or mediate the effect of descriptive and injunctive norms on contact tracing app adoption?) showed that resistance mediated the relationship between social norms at the beginning of the implementation phase and CTA use later on. Thereby, this demonstrates a mechanism through which the social context may exert its effects on CTA use: by reducing resistance.

The combined results of the research questions reveal that anxiety and reactance both fuel resistance to CTAs. This resistance remains important during the first months of the implementation process and is predicted by the social context in which people find themselves. The findings are based on exploratory analyses, but they imply that theories of innovation adoption and technology acceptance may make more precise predictions about behavior if they include anxiety and reactance, particularly at the start of an implementation. The finding that social norms are related to the experienced resistance and app adoption provides cautious suggestions for the application of social influence strategies for new public health technologies, well within ethical boundary conditions. The present research hereby advances our insight in reactions to the implementation process of apps, surveillance tech and e-health in a social context.

CRediT author statement

Iris Verpaalen: conceptualization, methodology, software, formal analysis, writing – original draft, visualisation. **Rob Holland**: conceptualization, methodology, writing – review & editing, supervision. **Simone Ritter**: conceptualization, methodology, writing – review & editing. **Madelon van Hooff**: conceptualization, methodology, writing – review & editing. **Wolfgang Ebbers**: methodology, writing – review & editing, project administration. **Lotty 't Hooft**: methodology, writing – review & editing, project administration. **Esther Metting**: methodology, writing – review & editing, project administration. **Laura Nynke van der Laan**: conceptualization, methodology, validation, investigation, data curation, writing – review & editing, supervision, project administration, funding acquisition.

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Declaration of competing interest

None.

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