


# “Fast, Easy, Convenient.” Studying Adoption and Perception of Digital Covid Certificates

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## Abstract

Digital vaccination, recovery, and test certificates play an important role in enforcing access restrictions to certain parts of the public life in Europe during the current phase of the COVID-19 pandemic. Such certificates represent an interesting showcase for digital security and privacy in the context of sensitive personal data.

In this paper, we take a look at which types of certificates and related apps people in Germany use for which purposes, which factors influence their adoption, and which misconceptions exist concerning the security and use of certificates. To this end, we report the results of a census-representative online survey in Germany ( $n = 800$ ) conducted in December 2021, complemented with 30 qualitative street interviews.

Most participants favor digital certificates over paper-based variants due to their ease of use and seamless integration into dedicated smartphone apps – more than 75 % of participants have installed one or more eligible app(s) on their phone. We find that older age, higher privacy concerns related to apps, and not being vaccinated are factors hindering the adoption of digital certificates.

## 1 Introduction

Over the past two years, the COVID-19 pandemic has caused massive restrictions to many aspects of public life all around the world, including lockdowns, curfews, cancellation of public events, limitations of international travel, and many more [31]. The broader availability of vaccines against COVID-19, especially in many countries in the Americas,

Asia, and Europe starting in 2021 [32], allowed gradual releases of several restrictions and a prospective return to normality. Since vaccinations have been shown to be very effective in preventing severe COVID-19 diseases [29, 36], many restrictions were particularly released for people who are fully vaccinated or have recovered from COVID-19. Some restrictions were also eased for people who tested negative for coronavirus.

In many European countries, e. g., Germany or Italy [13, 42] but also in Israel and some US states [14, 27], people have to prove their vaccination or recovery status, or provide a negative test result in order to attend certain public events or activities. Such requirements have become a catalyst for the development of *digital covid certificates* i. e., apps that can be used to prove the required status. Israel was one of the first countries to introduce the so-called *Green Pass* app in February 2021 [18], a QR code-based certificate scheme granting access to different activities. In the US, the state of New York has also introduced a digital QR code-based certificate in March 2021 (*NYS Excelsior Pass* app and *NYS Excelsior Pass Scanner* app) that serves as a proof of vaccination or alternatively proof of a negative coronavirus test [16]. In California, a similar digital vaccination certificate was introduced in August 2021, also enabling citizens to prove their vaccination [26].

One of the most widely deployed schemes is the EU Digital COVID Certificate, introduced by the European Union in June 2021 [10]. The underlying framework allows for interoperability of nationally issued certificates across all 27 EU member countries serving up to 450 million inhabitants. Similar to other systems, the EU certificate can be shown using a QR code and can be integrated into several dedicated mobile apps (e. g., CovPass and Corona-Warn-App in Germany). The certificate contains personal information such as name and date of birth, specifics of the vaccination, recovery, or test result (whichever applies depending on the type of certificate), and digital signatures for technical verification purposes. For *verifying the correctness* of certificates, specific apps (e. g., CovPassCheck in Germany) were introduced. These apps

validate electronic signatures of certificates and display the name and date of birth of the person for matching these data with ID cards.

In this work, we present the results of a census-representative online survey in Germany (n=800) on the use and perception but also the knowledge and potential misconceptions of digital covid certificates. Moreover, we are interested to learn the experiences of the respondents with this process, and adherence to correct verification in practice. We complemented our online survey with 30 street interviews with people who were obliged to verify certificates for access restriction purposes, e. g., shop owners, or restaurant staff. Finally, we observed the verification process of 80 businesses with access restrictions in the wild through convenience sampling. All three surveys were conducted in December 2021.

We find 70% of participants using apps to indicate their vaccination, recovery or test status, mostly for convenience reasons and due to the ease of use of certificate apps. Reasons against using digital certificates are for example privacy concerns and security concerns, and apps are less prevalent among participants at older ages.

Digital covid certificates provide an interesting showcase for digital security and privacy in an everyday application that is widely used by a broad audience: they contain not only personally identifiable information such as name and date of birth but also sensitive health information, i. e., vaccination, recovery, or test status. To the best of our knowledge, we are the first to study use, perception, and verification of digital covid certificates while being in wide-spread use.

In summary, our work makes the following contributions:

- We shed light on the prevalence of and attitudes towards paper-based and app-based covid certificates in a phase in which they highly facilitate participation in public life in Germany.
- Our quantitative and qualitative evaluations show that ease of use is a highly significant factor for the adoption of digital covid certificates, suggesting that easy to use solutions are desirable.
- We complement results of our consensus-representative online survey with qualitative insights from street interviews and with observations in the wild (random sample).

## 2 Related Work

Most related to our research is the work by Kowalewski et al. [20], who study the willingness to use of different variants of covid vaccination certificates in hypothetical scenarios prior to the introduction and use of these certificates. They find privacy, prior use of a corona app, and being against a vaccination obligation to be hindering factors for (hypothetical) willingness to use a vaccination certificate. On the other hand they find worries about the coronavirus and vaccination willingness to be

factors positively influencing the (hypothetical) willingness to use a vaccination certificate.

Other studies with regard to apps against the spread of the coronavirus, i. e., contact tracing apps, also find (app related) privacy concerns to have negative influence on the adoption but not on the continued use of these apps [25, 46, 49]. Other factors fostering the adaption of these apps are performance expectancy, social influence, technological knowledge, and apps benefits [25, 49]. The latter two factors are also found important for continued app usage of contact tracing apps [25].

A large body of work investigates the broader role of mobile apps in the pandemic in the contact tracing domain [1, 19, 21, 24, 39, 43, 52]. Individual studies also cover other types of apps for different pandemic-related purposes such as symptom checking [44] or accessing information about the pandemic [53]. A study Utz et al. [46] investigates predictors for the adoption of a broad range of app types, also finding that privacy is a significant factor for adoption.

Those findings are in line with more general related work, finding privacy (concerns) a relevant factor in decision-making about digital tools and interacting with online technology in a broad range of applications [9, 23, 38], as well as when using mobile health apps [15, 51, 54]. Also other factors influencing the use of mobile health apps, like age, education level, and e-health literacy, were identified [3].

General theories on (intention) to use technology, as the technology acceptance model (TAM), TAM2 and the Unified Theory of Acceptance and Use of Technology (UTAUT) [7, 47, 48] find the intention to use technology is based on factors like *perceived ease of use*, *perceived usefulness*, *social influence processes* (e. g., subjective norm) as well as *performance expectancy* (based on perceived usefulness and others) and *effort expectancy*.

## 3 Study Context

Digital COVID-19 certificates [12] have been introduced to establish a standardized and securely verifiable alternative to paper-based documents, such as the internationally recognized *yellow certificate of vaccination* document standardized by the *World Health Organization* (WHO) [8]. While such digital certificates are predominantly applied in Europe, they have also found adoption in other countries such as Israel and certain US states [16, 18, 26, 50].

In this section, we introduce the concept of the EU Digital COVID Certificate, and describe the current state of the pandemic in Germany, particularly focusing on restrictions in public life to provide the context in which we conducted our study. Whenever we refer to *covid certificates*, we include proofs for being vaccinated against COVID-19, recovered from COVID-19, or having a negative COVID-19 test result.

### 3.1 EU Digital COVID Certificate

In the European Union (EU), a digital covid certificate framework was rolled out starting in June 2021. It uses a QR code-based system and contains a cryptographic signature to protect against misuse or forgery. The certificate proves that a person

- is fully vaccinated against COVID-19,
- recovered from COVID-19,
- or has tested negative [11].

The information contained in the certificate includes personal data (e. g., name and date of birth), information on the vaccine (e. g., type and date) and technical details (e. g., certificate issuer, expiration date, and a unique identifier) [30]. In Germany these certificates can be included in three different apps: the *CovPass* app, the *Corona-Warn-App* (CWA), and the *Luca* app. The CovPass app was specifically developed for this purpose. The other two apps were introduced before for contact tracing (CWA) and event registration (Luca) and included the digital certificate as a new feature [5, 33, 37]. For privacy reasons, only the QR code and the person’s name are displayed within the app when the certificate is presented to a third party, e. g., for verification purposes (see Figure 1a).

To correctly verify the digital covid certificate, a so-called *verifier* app, such as the *CovPassCheck* app in Germany, is needed. Within the verification process, the verifying party uses this app to scan the QR code of the covid certificate [34]. For privacy reasons, the verifying person only sees whether or not the certificate is valid, along with name and DOB of the person to be verified (cf. Figure 1b), which have to be compared with an ID document. Whatever information is additionally shown on the device of the person to be verified (e. g., green bars, check marks, etc.) is irrelevant for correctly completing the verification process. Since the digital covid certificate contains more personal information like vaccination date(s), vaccine type, or recovery status, which is why letting another person scroll through the app is not advised due to privacy reasons.

In order to raise awareness of digital covid certificates, the German government provided a website explaining in detail how the EU digital covid certificate works and how to verify it correctly [35]. Governmental advertising campaigns on television and social media also drew attention to the digital covid certificate and how to store them in either of the two government-backed apps, i. e., CWA and CovPass. Within both apps, additional information was given to explain the correct verification of the QR code, i. e., using the CovPass-Check app.

### 3.2 Pandemic Situation in Germany

Due to high infection rates in Germany, measures referred to as *G-rules*<sup>1</sup> were successively introduced beginning in Au-

<sup>1</sup>e. g., 3G represents the requirement to be either vaccinated, recovered or tested negative. All German terms start with *g* (*geimpft*, *genesen*, *getestet*).

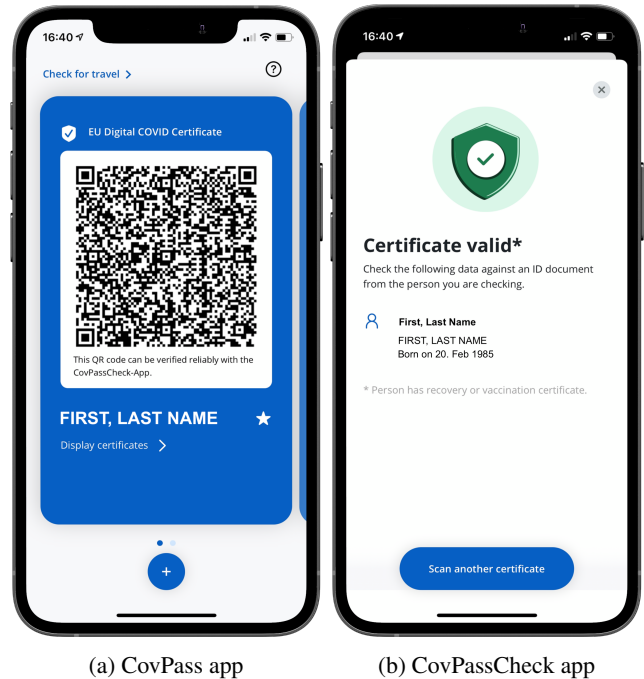


Figure 1: EU Digital COVID Certificate shown in the German CovPass(Check) app.

gust 2021 (see Table 1 for an overview). These measures were applied to certain parts of public life, e. g., to restrict attendance at professional sports events, and define what persons are eligible to access respective events [41]. In most of the 16 German states, both paper-based and digital covid certificates are accepted to prove the respective status, except for four states (i. e., Berlin, Brandenburg, Baden-Württemberg, and Saarland) that required digital covid certificates starting from September 2021 the earliest.

Over the course of the year, G-rules were continuously tightened and applied to attending large (sports) events, staying in hotels, non-essential shopping, using public transport, going to school or work, and others. Germany’s regulation obliged all these venues to verify attendants’ G-statuses. Thus, at the time of our study, certificates were required for all parts of public life except for shopping groceries and other essentials.

Table 1: Explanation of the G rules in Germany.

Access for	Fully vaccinated	Recovered	Negative Rapid Test	Negative PCR Test
3G	✓	✓	✓	✓
3G+	✓	✓		✓
2G	✓	✓		
2G+	✓ <sup>a</sup>	✓ <sup>a</sup>		

<sup>a</sup> Additional negative covid test required

## 4 Method

Parts of our study are based on the work of Kowalewski et al. [20] which allows us to compare their findings about *hypothetical* willingness to use (digital) vaccination apps with the actual use of them in the wild. As one of their hypothetical scenarios (*U3: Certificates required for various aspects of public life, vaccine available for everyone*) actually reflects the current (real) situation in Germany quite well, we will later compare our findings with theirs whenever applicable.

To study user adoption, knowledge, potential misconceptions and verification processes of (digital) covid certificates, we conducted three studies: a census-representative online questionnaire (n=800), short street interviews (n=30) in a city in western Germany, and random samples (n=80) of the verification process of digital covid certificate.

The online survey was conducted between December 03, 2021 and December 09, 2021 with 800 participants, using the software *Qualtrics* and the panel provider *Respondi*. The participants of our online survey received a monetary compensation for taking part in the questionnaire. Respondi handled participant recruitment, compensation and set quotas representative for the German population for gender, age, and education. Unfortunately, people over 70 are rarely represented in online panels. Quotas were matched perfectly for age and education, and there was a maximum deviation of 2% for gender. The education classification is based on UNESCO-ISCED Levels: Low (0-2), medium (3-4), and high (5-8) [45]. We list our participants' demographics in Table 2.

The 30 street interviews were conducted in one Germany city from December 07 to 21, 2021 by three researchers shortly after (digital) covid certificates became mandatory for many parts of public life (e. g., going to the cinema, restaurants, clothing stores or the hairdresser).

Our random sampling of the certificates' verification process was conducted in the same region as the interviews from December 07 to 21, 2021. Details on the three studies are presented in the following paragraphs.

### 4.1 Online Survey

We designed our online survey to gain insights into user preferences, perception and motivations for the use of digital and paper-based covid certificates. We focus on the most common certificate forms available in Germany:

- yellow certificate of vaccination (paper-based)
- Corona-Warn-App (digital)
- CovPass app (digital)
- Luca app (digital)

Whereas the CovPass app was specifically developed for handling covid certificates, the other two apps had already been available and were primarily used for contact tracing (CWA) and event registration (Luca) before.

Table 2: Participant Demographics in Online Survey

	Participants		Target
<i>Gender</i>			
Female	404	(50.5 %)	49 %
Male	392	(49.0 %)	51 %
Non-binary	1	(0.1 %)	0 %
Self	3	(0.4 %)	0 %
<i>Age</i>			
18–29	160	(20 %)	20 %
30–39	152	(19 %)	19 %
40–49	144	(18 %)	18 %
50–59	192	(24 %)	24 %
60–69	152	(19 %)	19 %
<i>Education<sup>a</sup></i>			
Low (ISCED 0-2)	230	(29 %)	29 %
Medium (ISCED 3-4)	264	(33 %)	33 %
High (ISCED 5-8)	304	(38 %)	38 %
<i>Privacy Disposition</i>			
Mean (SD)	3.28	(0.79)	
<i>App Privacy</i>			
Mean (SD)	2.69	(1.19)	

<sup>a</sup>Education classification is based on UNESCO ISCED 2011 Levels [45].

#### 4.1.1 Questionnaire

In this section, we outline the structure of our questionnaire. Due to our focus on digital covid certificates, we did not analyze all questions of the questionnaire for this paper. We will only address the questions we analyzed for this paper in this section. A complete version of the questionnaire can be found in Appendix A. All questions in the questionnaire were originally formulated in German to avoid misunderstandings. For documentation in this paper, all questions were translated to English.

#### General Questions and Experiences with the Coronavirus

We asked participants whether they or someone close to them has already been infected with the coronavirus (Q3–Q4), as well as their concerns of getting infected themselves (Q5) or that someone close to them might get infected (Q6).

**Covid Certificates** We also asked participants which COVID-19 related apps they have installed on their smartphone (Q7). Questions Q8 and Q9 list various items (i. e., purposes and activities) that may qualify for restrictions under COVID-19 measures. We selected items following related work [20] and extended the set with purposes and activities that were subject to (partially controversial) public discussions in Germany. For each item, we asked

1. whether a restriction and which restriction should apply (Q8; none, 3G, 3G+, 2G, or 2G+) and
2. which type of certificate should be required (Q9; none, paper-based, or app-based).

Moreover, we asked participants if they were already required to show their covid certificate (Q10), how effortful they perceived this (Q11), and whether they have already been vaccinated against or recovered from the coronavirus (Q12). Subsequently, we showed them a list of covid certificates (e. g., CovPass app or yellow certificate of vaccination) to indicate which of these variants they typically use to prove their vaccination, recovery or test status (Q13/Q14). Based on whether the participants have indicated to use a paper-based or digital covid certificate (Q13/Q14), we further asked them to explain their decision, i. e., deciding for or against the respective certificate variant (Q15/Q16).

**Certificate Verification Process** To get insights into the verification process, we asked participants to describe how their digital certificate was verified (Q17) at their latest access control situation(s). In question Q21, the participants were asked to indicate the perceived ease of use of the used covid certificate variant. To evaluate participants' knowledge of digital covid certificates, especially QR codes and the correct verification process, question Q23 consisted of various correct and false statements related to this topic. For the analysis we re-coded the answers to the false questions to compute a *knowledge score*, for which higher values indicate more knowledge. Cronbach's alpha is acceptable for the knowledge score ( $\alpha = .7$ ), which is why we include this score in our analysis.

In question Q24, we asked participants to name the most important aspects for verifying digital certificates correctly, including what they think needs to be verified and what they perceive to be the (technical) security indicators.

**Attitudes Towards Measures Against the Spread of the Pandemic** In order to understand more about our participants' perceptions regarding measures taken against the spread of the pandemic, we asked them questions whether they believed that specific measures (e. g., the 3G rule, vaccinations, or contact restrictions) contributed to containing the spread of the coronavirus (Q33). Cronbach's alpha shows a good fit for these attitude items, which is why we used them as an *attitude scale* ( $\alpha = .9$ ).

**Privacy Disposition** The individual vaccination but also the recovery, and test status represent personal health data. Storing this data within an app and linking it with personal information (e. g., name and date of birth) but also providing this data during a mandatory verification process may raise privacy concerns and questions regarding general data pro-

tection. To get insights into participants' privacy attitudes we used two validated three-item *Privacy Scales* [4, 22]:

1. The first part consisted of three questions to measure participants' general privacy disposition (Q34).
2. We adopted the second set of questions to our digital covid app context (Q35).

We added a fourth question to both scales covering specifically concerns related to health data. Therefore, the two scales consist of four questions each. As Cronbach's alpha ranges from acceptable (Q34,  $\alpha = .7$ ) to excellent (Q35,  $\alpha = .96$ ), we use both scales as described.

## 4.2 Street Interviews

The street interviews expand our research to the views and experiences of people *verifying* covid certificates. We interviewed people working in venues that were obligated to control certain regulations concerning the coronavirus. We spread our interviews across a variety of business sectors. 18 interviews were conducted in retail, i. e., clothing or cosmetics stores, seven were done in hotel and catering business, three in the fitness and health field, and two in cinemas. All of them required 2G rules at that time. We renounced asking demographics to keep interviews as short as possible and to protect participants' privacy. After getting the agreement to participate we asked questions regarding

- the current regulations concerning the coronavirus at the venue
- which restrictions they had to control
- how they verified covid certificates
- how thoroughly they think they performed the verification

Our complete interview included additional questions, which we do not describe here, as we consider them out of scope for this paper. The complete interview guideline including all questions can be found in Appendix B. As the interviews were really short, we refrained from transcribing them. We took notes during the interviews and later grouped them to categories for the analysis.

## 4.3 Sampling the Verification Process for Digital Certificates

In addition to the perception of our participants and the experiences of people verifying covid certificates, we also wanted to gain insights into how the verification process of digital covid certificates was carried out in the wild. For this purpose, three researchers entered 80 stores and businesses for which the 2G restriction applied, including fashion stores, cinemas, theaters, and restaurants. We did not interact with employees but only observed the verification process. We focused only on the verification process for digital certificates (e. g., Corona-Warn-App or CovPass app) and documented

the complete process distinguishing between the following verification levels:

- L1 No verification
- L2 Short glance (no scan and no ID card required)
- L3 Glance with ID (no scan but matching the personal data with the ID card)
- L4 Scan only (no ID card required)
- L5 Scan with ID (i. e., the correct verification process)

The correct verification of digital covid certificates consists of two factors (level L5): scanning the QR code with a suitable app (e. g., CovPassCheck) and matching the shown personal data with the data of the person’s ID card (i. e., first name, last name, and the date of birth).

#### 4.4 Research Ethics

Our department does not have an institutional review board. Instead, our study followed best practices of human subject research and data protection guidelines. To minimize any potential adverse effects from the study we followed the ethical principles laid out in the Belmont report [28]. Specifically we sought informed consent at the beginning of the study and participants were informed about the topic of our study, data protection, data processing, and pseudonymization of their data, as well as that they could withdraw from the study without any negative consequences at any time. We did also ensure that the panel provider (Respondi) is certified according to ISO 20252:2019, relevant for consumer research.

#### 4.5 Limitations

As Germany is organized federally, not all covid restrictions were identical for all German states. In four states, only digital covid certificates were permitted. However, we believe that the restrictions were similar enough during the time of our study (see 3.2). For our interviews, the small number of interviews and the location restriction to a single city are limitations. The same limitation applies to our random sampled verification process, which was carried out in the same region as the interviews. Additionally, we refrained from collecting demographic data for these two studies. As we used an online panel for our online survey results might tend towards app usage, as online panel works might favor digital tools. Other than that, an online survey will never be able to fully capture the complexity of interacting in real-world situations, which is why we used interviews and convenience sampling as further survey methods. Finally, most of the restrictions we asked about being already in place during the time of our survey might have biased participants to opt for them.

### 5 Results

In this section, we present the main results of our study, centered around the results of our online survey.

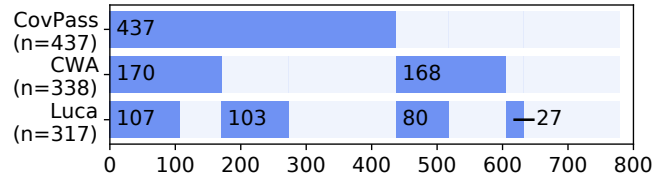


Figure 2: Overview of apps eligible to keep covid certificates installed on our participants’ smartphones (Q7). Bar segments placed below one another denote shares of participants who have installed multiple apps on their phones.

#### 5.1 Overview of Covid Certificate Use

Figure 2 shows which covid certificate apps participants reported to have installed on their smartphones. These include the CovPass, CWA, and Luca app, with some participants using more than one app on their phone which is denoted by bar segments placed below one another in the figure. Overall, 79 % of our participants ( $n = 632$ ) have at least one of the three apps installed. Out of the remaining 168 participants, 20 denoted to not own a smartphone (Q1).

When asked about the means primarily used to prove their vaccination or recovery status (Q13), 77 % of the respective participants (553 out of 720) named one of these three apps. Paper-based variants (e. g., the yellow WHO vaccination card) were preferably used to indicate the vaccination or recovery status by 20 % of eligible participants ( $n = 142$ ). Interestingly, the numbers of willingness to use apps in hypothetical scenarios are much lower, as the comparison to findings by Kowalewski et al. [20] shows. They reported 37 % of participants to be willing to use a mobile app to prove their vaccination status (compared to 44 % in favour of paper-based certificates), and 12.5 % being indecisive.

For proving a negative result of a covid test (Q14), the picture is a bit different. We only asked this question to participants who were unvaccinated or did not disclose their vaccination status ( $n = 93$ ). While 50 of these participants indicated to never use any means to provide a negative test result (e. g., when they never provide such a result at all), the remaining responses ( $n = 43$ ) are almost evenly split across one of the apps, other digital variants, and paper-based variants. However, due to the very small subsample, we do not intend to make any claims about generalizability w. r. t. app adoption for providing negative test results. Detailed responses to these two questions are listed in Table 3.

**Perceived Effort** Overall, the perceived effort (Q11) required to use covid certificates was reported as rather low. The distributions of perceived effort for both paper-based and digital certificates are illustrated in Figure 3.

55 % of participants who primarily used paper-based certificates assessed the use of certificates to be *not effortful* or *a little effortful*, i. e., the lowest two levels on an equidistant

Table 3: Type of certificate primarily used (Q13/14).

Certificate Type	Vax / Recovery	Test Result
<i>Digital variants</i>		
CovPass	360 (50.0 %)	6 (6.5 %)
CWA	154 (21.4 %)	1 (1.1 %)
Luca	39 (5.4 %)	4 (4.3 %)
Other app	2 (0.3 %)	1 (1.1 %)
Other digital variant	4 (0.6 %)	12 (12.9 %)
<i>Paper-based variants</i>		
WHO certificate	112 (15.6 %)	—
Other	30 (4.2 %)	14 (15.1 %)
None of the above	19 (2.6 %)	50 (53.8 %)

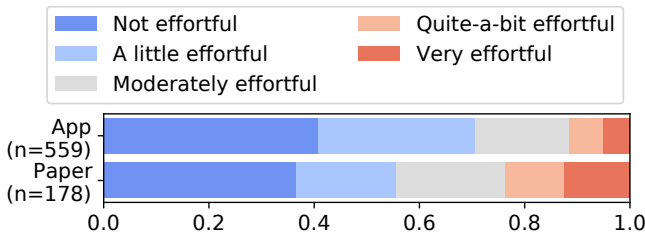


Figure 3: Perceived effort required to use digital (app-based) and paper-based covid certificates.

five-point scale ( $mean = 2.44 \pm 1.94$ ). For digital certificates, 70 % of the respective participants assessed the required effort to be on one of the lowest two levels ( $mean = 2.05 \pm 1.30$ ). Compared to previous findings assessing the hypothetical effort of vaccination certificates [20], the perceived effort of real usage seems to be slightly lower for both digital and paper-based covid certificates, and the difference between the two types is larger.

**Access Restrictions** Our online survey participants are generally in favor of restrictions applied to specific aspects of public life (Q8). For all purposes except for access to grocery stores, more than 80 % preferred one of the different types of restrictions with slight variations between purposes.

Confirming other studies [20], our participants seem to be willing to accept stronger restrictions for exceptional purposes such as *international air travel* or accessing *large events*, compared to e. g., *shopping*. When asked about the type of certificate they would use for the different purposes (Q9), we see a similar picture with participants being generally in favor of using certificates, with similar variations depending on the purpose. Paper-based certificates are preferred by approximately 25 % of participants for the majority of purposes. We observe slight deviations for access to grocery stores (20 %) and for schools (30 %). Across all purposes, the fractions of participants preferring digital certificates are in a range between 45 % and 70 %.

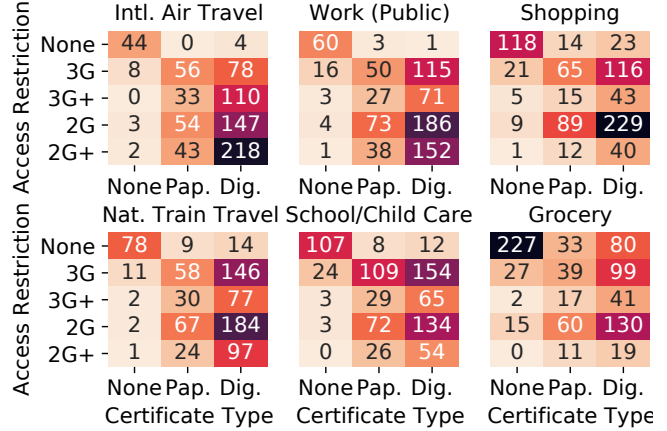


Figure 4: Numbers of participants grouped by all possible combinations of responses to Q8 (y-axis, preferred type of access restrictions) and Q9 (x-axis, preferred type of certificate) for six selected purposes.

We were also interested in whether and how answers on the strictness (Q8) and on the type of certificate likely used (Q9) might be connected. To this end, we evaluated the preferred type of certificate of participants who are in favor of a certain type of access restriction. Confusion matrices in Figure 4 show numbers of participants who responded with any combination of responses to Q8 and Q9 for six purposes. We selected these items because they represent different types of activities or have been subject to controversial public discussions in Germany. It seems that participants who are in favor of stronger restrictions (e. g., 2G or 2G+) tend to have stronger preferences for digital certificates. Most plausibly, participants who oppose access restrictions (Q8=none) by far prefer to not use any type of certificate (Q9=none).

**Certificate Use in the Wild** The responses we received in street interviews with business owners only partly match the data obtained in our online survey. In the interviews we found that the estimated ratio of digital covid certificates varied across business types. While in hotels and catering, we received diverse responses ranging from 50 to 90 % shares of digital certificates, cinemas, health industry, and the majority of retail reported an average of 85 to 99%. Particularly the latter seem to be higher than responses provided by online participants, among whom digital certificates were preferred by a maximum of 70 %, depending on the purpose.

## 5.2 Predictors for Digital Covid Certificate Use

To identify factors which foster the use of digital covid certificates, we conducted a logistic regression analysis which is the suitable method for binary outcome variables and metrical or categorical predictor variables. The use of digital covid certificates serves as outcome variable and is determined as follows: we combined responses to Q13 and Q14 into one

Table 4: Logistic regression analysis for using digital covid certificates based on the online survey data. A positive estimate and an odd ratio above one indicate higher odds of using a digital covid certificate. Significance levels are indicated with stars (\* $p < .05$ , \*\* $p < .01$ , \*\*\* $p < .001$ ). (n = 559)

Independent variables	Est.	Odd
<i>Gender (baseline: male)</i>		
Female	0.35	1.42
<i>Education (baseline: medium education)</i>		
Low education	-0.05	0.95
High education	0.70	2.02
<i>Age (baseline: 40-59)</i>		
18-29	0.40	1.48
60-69	-0.86*	0.42
<i>[Q3/Q4]: Coronavirus infection (Baseline: no)</i>		
Yes	-0.08	0.92
<i>[Q5/Q6]: Worries about infection</i>		
	-0.04	0.96
<i>[Q12]: Vaccination status (baseline: vaccinated)</i>		
Not vaccinated	-2.81***	0.06
<i>[Q21]: Ease of use of covid certificate</i>		
	0.89***	2.42
<i>[Q23]: Knowledge about covid certificate</i>		
	0.20	1.22
<i>[Q33]: Attitudes towards measures against the spread of the coronavirus</i>		
	0.03	1.03
<i>[Q34]: Privacy disposition</i>		
	0.19	1.21
<i>[Q35]: App privacy</i>		
	-0.37*	0.69

binary variable by assigning “1” if a participant used a digital variant in either case and “0” otherwise. As we are interested in the general use of digital covid certificates, we neglect the respective certificate content, i. e., vaccination, recovery, or test result. We use the following variables as predictors for the model:

- Gender, Education, Age
- Coronavirus infection (Q3/Q4)
- Worries about coronavirus infection (Q5/Q6)
- Vaccination status (Q12)
- Ease of use of covid certificates (Q21)
- Knowledge about covid certificates (Q23)
- Attitudes towards measures against covid spread (Q33)
- Privacy disposition (Q34), App privacy (Q35)

We introduce two factors that are derived from the responses to multiple questions:

- For Q3 and Q4, we created a new factor “Coronavirus Infection” indicating “yes” for participants answering “yes” to at least one of these questions and “no” for participants answering “no” to both of these questions.
- For Q5 and Q6, we grouped the answers to a score indicating “worries about coronavirus infection”.

Table 4 shows the estimates and odd ratios of all predictors. We find four predictors that significantly influence the use of digital covid certificates. Whereas *ease of use* of covid certificates (Q21) increases the odds of using digital certificates, *older age* (60-69), *not being vaccinated* (Q12), and having more *privacy app concerns* (Q35) negatively influence the odds of using digital covid certificates. Odd ratios for *ease of use* indicate that the odds of using a digital covid certificate increase with 142% (*oddratio* = 2.42) for an increase in ease of use by 1 on a 5-point rating scale. Participants who are older (*oddratio* = .42), unvaccinated (.06), or who have higher app privacy scores (.69) are less likely to use a digital covid certificate. This confirms previous findings by Kowalewski et al. [20], who reported privacy disposition as a hindering factor for the (hypothetical) willingness to use vaccination apps, vaccination willingness positively influencing the willingness to use vaccination apps. However, age was no significant factor in their model and ease of use was not included due to the scenarios being hypothetical.

Even though only one privacy score, i. e., app privacy, is a significant predictor for the use of digital covid certificates, we conduct Wilcoxon test to see if people using digital covid certificates differ significantly in their (app) privacy dispositions from people who do not use digital covid certificates. We find significant differences between these two groups for both, privacy disposition ( $p < .01$ ) and app privacy ( $p < .001$ ). People not using a digital covid certificate show higher values for both privacy disposition (*mean* = 3.43 vs. *mean* = 3.22) and app privacy (*mean* = 3.32 vs. *mean* = 2.42).

### 5.3 Certificate Preferences

Based on whether participants have used a paper-based or digital covid certificate (Q13/Q14), we further asked them why they decided for either variant over the other one, i. e., why they chose the digital certificate (Q15) or why they preferred the paper-based alternative (Q16). To get further insights into the participants’ reasons to use either variant, Q15 and Q16 were open-ended questions.

**Coding Procedure** We used an iterative coding procedure to evaluate open-ended responses to these questions. The same procedure also applies to questions Q18 and Q24 presented later in this paper. Two researchers independently assigned codes for each open-ended question and each participant’s response could be assigned multiple codes. Depending on the number of responses, in a first step, an independent coding scheme was created based on a larger number of responses (approx. 100 for each open-ended question). Subsequently, a common coding scheme was agreed upon, followed by coding the remaining responses by one researcher, and finalized by a mutual validation of the responses’ codings.



**Preference for Using Digital Certificates** When asked about their preference for using digital certificates and deciding against using a paper-based certificate, we observed various reasons. The most common argument in the evaluated online survey responses (268 of 529 responses) is that participants carry their smartphone with them anyway (P603: “*Because I have my smartphone with me at all time*”), followed by the ease of use of digital certificates (234 of 529 responses), including the easier handling compared to paper-based certificates (P284: “*I always carry my smartphone everywhere I go. I would just forget the paper certificate*”). Ease of use also comprises statements indicating the (more) convenient use of the digital variant (P376: “*Because I find it very convenient that both partners can be stored on one smartphone. . .*”), the overall faster verification process (P657: “*More useful and works out to be more quick for me*”), and the increased practicability (P741: “*Because it [the app] is more practical*”). The fear of losing the paper-based covid certificate, especially the yellow certificate of vaccination, is also a frequently stated reason for using a digital covid certificate (60 of 529 responses). Besides fear of loss (P20: “*Fear of losing the vaccination card*”), these also include unintentionally destroying the paper variant (P581: “*. . . a paper vaccination card can get torn, smudged, or may get lost*”) and the perceived high value of the yellow certificate of vaccination, which is used for more than just vaccination against the coronavirus (P62: “*Vaccination card is too valuable for me to carry around all the time.*”). For 26 out of 529 participants, the security of the QR code-based digital covid certificates or the forgeability of paper-based covid certificates was the primary reason for choosing the digital variant (P317: “*More forgery-proof, can be scanned or should be scanned*”, P512: “*It is more secure*”, P17: “*Paper is too easy to forge, but app-based proofs are cryptographically secured*”).

Requirements imposed by some German states, events, or businesses to only recognize digital certificates or at least certificates including a QR code (12 of 529 responses) can also be a driving factor for using a digital variant (P189: “*Paper-based is not accepted everywhere*”).

**Reasons to use Paper-Based Certificates** To gain insights into participants’ reasons to use a paper-based variant, we asked the corresponding participants why they decided against using a digital covid certificate (Q15). We received 176 answers for this question and found similar reasons as for the preferred use of app-based certificates. Participants mentioned greater ease of use compared to digital variants ( $n = 25$ , e. g., P290: “*Faster to reach than the smartphone*”), carrying the paper with them anyways ( $n = 11$ ), and fear of technical issues ( $n = 23$ ) as reasons to use a paper version. Other reasons for using a paper-based covid certificate were not owning a smartphone ( $n = 16$ ), regularly forgetting the smartphone ( $n = 19$ ), or unavailability of a digital version ( $n = 17$ ). 13 participants stated privacy concerns and 12 participants stated security

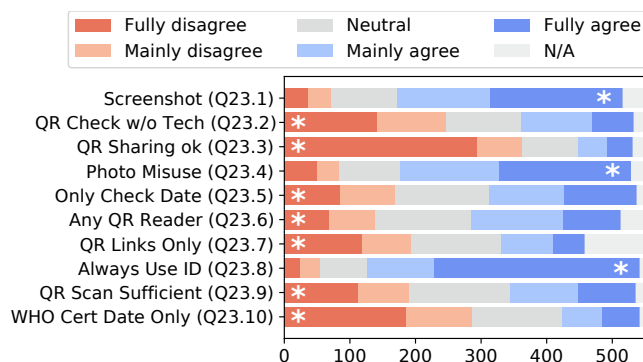


Figure 5: Participants’ agreement to statements regarding certificate QR codes and correct verification of digital covid certificates. Correct responses are labeled with an asterisk (\*).

and privacy concerns for their decision against digital covid certificates (P532: “*Why should I let the apps locate me*”).

## 5.4 Knowledge of Digital Covid Certificates

Despite knowledge not being a significant predictor for the use of digital covid certificates, the answers to a set of knowledge questions in the survey, i. e., Q23, can provide valuable insights into users’ perception and misconceptions of certificate apps. We asked participants to indicate their level of agreement to statements mainly focusing on QR codes and the correct verification process of digital covid certificates (Q23). Here we only report answers of participants who indicated to use digital covid certificates. The distribution of their responses to all 10 statements is shown in Figure 5. In an open-ended question (Q24), we additionally asked participants about the most important aspects w. r. t. verifying digital certificates.

The knowledge score for participants using digital covid certificates ( $n = 559$ ) is 3.45 (scale ranging from 1 to 5), indicating only moderate knowledge about these certificates, the correct verification, and especially QR codes. The statement for which we observed the most “*I do not understand the statement*” answers (18%), is Q23.7 “*QR-codes can only link to websites. URLs that simply look a bit different*”. 128 participants (23%) (rather) agree with this statement and 25% of participants indicate a neutral position to this statement. Therefore, more than half of our participants do not know that QR codes can do more than link to websites or are not sure about that.

However, 44% of the surveyed digital covid certificate users know that it is not possible to verify the validity of a certificate QR code without technical help (disagreement to Q23.2). The majority of participants (62%) also know that a picture or screenshot of a QR code can also be read by a QR code reader (agreement to Q23.1). 65% of participants know that it is not wise to publicly share a picture or screenshot

of their QR code from the covid certificate (disagreement to Q23.3). 63 % of users are aware that a picture or screenshot of their QR code could be used (maliciously) by other people (agreement to Q23.4). This shows that users are aware of possible malicious use of and cautious behavior regarding their covid certificate QR code.

Some participants also know that scanning the QR code is not sufficient for a correct verification of the digital covid certificate, as 34 % disagree with the statement “With the Corona apps, it is sufficient to scan the QR code for a correct check” (Q23.9). Interestingly, 34 % of participants agree to this statement and 28 % are not so sure, i. e., used the answer “3-neutral”. This shows that for some participants matching the information of the certificate with an identity card does not seem an important aspect, they believe scanning the QR Code is sufficient. However, the majority of digital covid certificate users (74 %) agree to the fact that a verification is only correct in combination with an ID card (agreement to Q23.8). Answers to question Q24 show that 109 participants explicitly name the QR code as an important aspect for a correct verification (code “Scan the QR code”, “QR code”). Some of them even named the correct process, i. e., “scan the QR code and match w/ ID card”. Those participants understood the importance of the QR code as a security feature. Others just named the date of the final vaccination as one of the most important aspects for verifying the certificate. Concerning the security aspects of verifying covid certificates, 226 of 442 participants describe that a complete verification is only valid in conjunction with the ID card (P768: “Name, Date of birth matching with identity card”, P551: “Comparison with ID card and scanning the QR code”). Matching the information with an identity card as an important aspect of the verification process, was agreed upon by 74 % of our participants within the knowledge questions (agreement to Q23.8). Several (92) participants stated they do not know which aspects are (most) important to verify digital certificates (P766: “Unfortunately I don’t know”, P726: “No idea”, P679: “Unfortunately, I have too little knowledge of this to give more precise information”).

## 5.5 Misconceptions of Digital Covid Certificates

Some answers to question Q24 in our online survey reveal misconceptions about QR code-based certificates. 18 participants incorrectly believed that showing a screenshot of the QR code to verify a covid certificate, is not valid (P65: “The code is not allowed to be a photo”). A few more participants ( $n = 13$ ) directly mentioned that a respective app must be used, e. g., CovPass or Corona-Warn-App (P7: “It must be checked that it is not a screenshot, but is in the app”). Despite using a screenshot is perfectly fine both in terms of security and privacy. Moreover, four participants thought that scrolling (i. e., scrolling up and down the screen of the app on the owner’s smartphone) is sufficient to verify the certifi-

cate validity (P332: “You can move it [the screen] back and forth”). This is also a misconception found in the interviews (PI3, PI24: “I scroll up and down [...] like that I ensure it’s real”).

## 5.6 Verification Processes in the Wild

We now compare the results regarding the verification of digital covid certificates obtained in all three surveys.

Table 5 shows the frequencies of correct verification (procedure L5) for all of them: Random sampling of businesses, online survey, and street interviews. The most correct verification were named in the interviews: 50 % of the interviewees reported the procedure for the correct process – scanning the QR code *and* matching the personal data with an identity card, to make sure the certificate is valid *and* shown by the right person. In both the online survey and the random sampling, the frequencies for correct verification are lower (34 % and 37 %). Missing checks were not mentioned in either the online survey nor the street interviews but we discovered them in our sampling. Only a short glance at the digital certificate with matching the ID was observed in around 30% of all observations.

In our street interviews with business owners, responses describing checks of digital covid certificates revealed that about half of the checks are partially incorrect or missing important steps. Such checks are either missing the ID comparison or a scan with an appropriate verification app. This is also in line with our online survey, as some participants were not aware, that comparing personal data with the ID is important. A factor that seemed to positively influence the correct checks was when interviewees were provided a device for scanning purposes by their employer. This was mentioned explicitly by seven of our participants. Four participants mentioned to refrain from scanning because they *would* have to use their personal device which they did not feel comfortable with. All interviewees were sure that they conducted the verification thoroughly or very thoroughly. However, some justify this rating by stating they performed the checks *as good as they could*.

Table 5: Coding statistics – Procedure to verify digital covid certificates. Provided for the sampled checks, the open-ended responses within the online survey (Q18), and the interviews (Q7/Q8).

Procedure	Sample	Frequencies	
		Online Survey	Interviews
<b>L1:</b> No control	(5) 6 %	-	-
<b>L2:</b> Short glance	(7) 9 %	(45) 34 %	(5) 17 %
<b>L3:</b> Glance w/ ID	(31) 39 %	(33) 25 %	(9) 30 %
<b>L4:</b> Scan only	(7) 9 %	(9) 7 %	(1) 3 %
<b>L5:</b> Scan w/ ID	(30) 37 %	(44) 34 %	(15) 50 %
<b>Overall responses</b>	80	131	30

In street interviews we also identified misconceptions regarding the correct verification of digital covid certificates, that fall in line with the reported misconceptions from the survey. Some participants thought that scrolling through the app would not only be sufficient but important to determine whether the certificate is valid. Some others did not identify the QR Code as a security feature (PI10: “*We look if there are two vaccinations and check the date of the second vaccination. We only look by eye, the QR isn’t helpful for us*”). Others thought the color with which the certificate is shown indicates whether it is valid or not. One participant even mentioned “scanning” with the CWA and that it is “*odd having so much personal data of the customers on the phone*” (PI8). A similar incident has been reported in the media [17]. The CWA suits the purpose of storing the personal digital covid certificate and is not supposed to verify certificates. Scanning certificate QR codes with the CWA leads to storing the (foreign) QR code as well as the information contained within the QR code in full detail in the app. The proper verification app (CovPassCheck app) displays only the validity and basic personal information for the comparison with an ID card (1).

## 6 Discussion

In this study, we aimed to identify factors that influence the adoption and perception of digital covid certificates, designed to securely indicate users vaccination, test, or recovery status. As more than one app existed in Germany our results are not tailored to app design but are more broadly. We also refrain from drawing broader conclusions for other contexts, as we consider the COVID-19 pandemic as exceptional. Our results must be seen in light of restrictions in Germany during the time of our survey: Access to substantial parts of public life was only permitted with some sort of covid certificate, so one was mostly bound to use some form of covid certificates and had the choice between paper-based and digital covid certificates.

### 6.1 Acceptance of Digital Covid Certificates

The majority (79 %) of our participants use at least one app that offers the feature to include a digital covid certificate, which is in line with the official download numbers of the Corona-Warn-App (40 million downloads as of January 2022) and the CovPass app (23.5 million as of November 2021). The slightly higher adoption rate in our study might be due to the online panel, i. e., participants with potentially higher technology use. 70 % of survey participants usually use a digital covid certificate to indicate their vaccination, recovery, or test status when needed. The acceptance rate for app-based certificates is high, which is different from related work by Kowalewski et al. [20], finding that only 37 % of participants are willing to use a digital vaccination certificate, while 44 % would prefer a paper-based version. However, Kowalewski et

al. only surveyed usage *intention* of different implementations of vaccination apps not actual usage, as there were no vaccination apps available during the time of their study. Our results reveal that actual usage of digital covid certificates, especially when some sort of certificate is mandatory for many activities, differs from hypothetical intention to use a digital version.

Concerning access restrictions for aspects of public life, 80 % of our participants are in favor of restrictions for the mentioned purposes in this study (except for grocery shopping, see answers to Q8). As almost all of the presented purposes were restricted during the time of our study, this shows the acceptance of the measures undertaken to contain the pandemic. It seems that users favor stronger restrictions for exceptional purposes like international air travel, which confirms previous results [20]. Whereas at the workplace 3G restrictions applied in Germany, we observe high numbers in favor of stronger restrictions ( $n = 449$ ). As also many people favor 2G or stricter restrictions for national train travel ( $n = 372$ ), this suggests that people prefer stronger restrictions for more crowded environments like airplanes, trains, or workplaces such as offices. Most answers for no restrictions were observed for grocery shopping ( $n = 384$ ), but opposite to German regulations 416 participants favor some restrictions (at least 3G) for grocery shopping.

Overall, digital certificates are favored over paper-based certificates by 45% to 70% across all purposes. It also seems like participants favoring stronger restrictions tend to prefer the use of digital certificates over paper-based ones.

### 6.2 Predictors for the Use of a Digital Covid Certificate

We find ease of use to be a significant predictor for the use of these digital certificates, not only in our logistic regression analysis but also in the open responses, in which 234 out of 529 participants use a digital certificate due to its ease of use. These findings are in line with both technology acceptance models, like the TAM, TAM 2, and UTAUT [7, 47, 48] as well as with related work researching the intention to use mobile apps [40]. Users seem to think that the easiest way to indicate their vaccination, test, or recovery status is using a corresponding app, e. g., because they carry their smartphone with them anyway (“*Because I have my smartphone with me at all time*”). Participants also stated that, by using an app, they are less likely to forget their certificate and some fear to lose their paper-based vaccination certificate, which they value as all their vaccinations (prior to covid) are included.

Another significant but hindering predictor for the use of digital covid certificates, is privacy concern related to apps. Participants with higher privacy concerns, i. e. more privacy cautious behavior, are less likely to use one of the appropriate covid apps. This is in line and conforms with related work on online technology [9, 23, 38], mobile health apps [15, 51, 54], contact tracing apps against the spread of the coronavirus [25,

46, 49] as well as (hypothetical) willingness to use mobile vaccination apps [20].

On the other hand, we observe that only 13 out of 176 participants using a paper-based certificate do so because of privacy concerns with the digital certificate. Both privacy disposition and privacy apps scores being rather moderate in our sample ( $mean = 3.28$ ,  $mean = 2.69$ ) indicates that participants have moderate privacy concerns at most. These privacy scores are similar to the ones Kowalewski et al. [20] observed. Therefore, our results show that when participants are not directly asked for privacy, it is only named in very few cases as a hindering aspect for using digital covid certificates. This might be due to the fact that both the CWA and the Luca App were already in use for contact tracing and event registration in the earlier phase of the pandemic, and the covid certificate functionality was added at a later point. Thus, the decision to use the app had already been made at a previous point and for a different functionality and privacy reasons were assessed already. This is in line with previous findings: It was shown earlier for contact tracing apps [25] that once the decision for using an app has been made, privacy is not a predictor for continued app usage.

People who do not plan on getting vaccinated are less likely to use a digital certificate. This might be due to the increased effort to integrate a negative test in the respective apps, as not all test facilities offer a QR code to scan test result. Older age (60 – 69) is also identified as a hindering predictor for the use of digital covid certificates, which might be due to generally lower adoption rates for technology as well as less smartphone use of older people [2, 6] (P205: “*No smartphone*”, P14: “*Because I don’t own a smartphone*”).

### 6.3 Knowledge and Misconceptions regarding Digital Covid Certificates

Regarding the knowledge of digital covid certificates with focus on QR codes, we observe most unsure answers for what a QR code can point to. People are not sure if QR codes are just different forms of links and can only point to websites. This might be due to users’ little exposure to QR codes, except for when they are pointing to websites. For most users, covid certificates are a new use case for QR codes. The importance and functioning of the QR code could be better explained to users, e. g., within the app. With more information maybe more users would use digital covid certificates and maybe even feel more safe using them. Out of 529 participants, only 26 mentioned the security as a reason to use the app and not the paper certificate and 12 participants use the digital certificate due to the validity of the QR code. This shows that at least a minority of users seem to understand and value the QR code as a valid security feature, but most people are not aware of that. However, most users know that sharing ones QR code publicly is not reasonable and that pictures or screenshots of QR codes can be used maliciously by others.

### 6.4 Perception and Misconceptions of Verifications

Regarding the correct verification process of digital covid certificates we observed one person using the CWA for the verification process in our interviews. However, the CWA is not suitable for the verification process as it extracts and stores the entire data of the digital covid certificate. The respective app to verify certificates is the CovPassCheck app.

Across all three surveys, we observed the highest estimations of correct verification processes in the interviews (50%), however these were just self-reports and the results of our sample and online survey with only 37% and 34% correct controls, hint to lower correct verification processes than self-reported by the verifiers. Such high rates of incorrect verification processes also indicate that governmental campaigns (e. g., online, TV) might have not reached all audiences in an appropriate way, or that there is lack of trust in these campaigns. However, lack of awareness and understanding may not be the only reason: Instead, interviewees did not want to use their own device for scanning the QR code and therefore refrained from scanning overall.

Therefore, a more in-depth analysis of the reasons for low adherence to correct verification is required and could be taken up by future work. For comparable situations in the future, we additionally recommend to not only provide information on specific processes, but to also allow asking for feedback and further consultation, and to actively support or assist those individuals who are in charge of executing quasi-official tasks such as verifying certificates.

## 7 Conclusion

Digital covid certificates are preferred by our participants over paper-based variants due to their ease of use and seamless integration into dedicated smartphone apps. Users perceive the apps as easy and convenient to use, carry their smartphone with them all the time anyway. Unfortunately, the security-related processes of scanning the QR code and matching it with the bearer’s ID card are not always followed or even known by people obliged to check certificates. Therefore, more information on security aspects of digital certificates and the correct verification process are needed, especially for people checking certificates. For further app advancement and development, we suggest to make the app as easy to use as possible, to avoid unclear design and to give users information on how to use the app, especially for verification purposes. Privacy and security indicators should be explained to users. However, our results are limited by the fact that covid certificates were mandatory for many aspects of public life in Germany, e. g., eating in a restaurant. Therefore, use and perception of these apps might be different and not directly transferable to other countries and societies.

**Acknowledgments** This research was supported by DFG (German Research Foundation) under Germany’s Excellence Strategy – EXC 2092 CASA – 39078197 and by the PhD School “SecHuman” by the federal state of NRW, Germany.

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## A Questionnaire – Online Survey

**Welcome Text** Study on the topic of 2G-/3G certificates. Thank you for your interest in our study!

In this study we will ask a series of questions about vaccination, recovery, and test certificates. The purpose of this survey is to get a comprehensive understanding of 2G-/3G certificates in the context of the coronavirus pandemic of the German population. By participating, you can make a valuable contribution to this purpose.

**Purpose:** This scientific study investigates your perception of 2G-/3G- regulations by means of (digital) proofs, as they are required (e. g., for cinema visits or other activities and events).

**Prerequisites:** To participate in this study, you must be at least 18 years old.

**Duration:** Participation in the study is expected to last 20 minutes. There are no anticipated risks for you to participate. Please answer the questionnaire as honestly as possible. If you no longer wish to participate in this study, you may discontinue at any time as long as you have not yet submitted your answers or they have not yet been evaluated.

**Contact:** The study is conducted by researchers [...]. If you have any questions about or problems with this research, please feel free to contact [...].

**Data protection:** Your responses in this study will be linked to your Respondi-ID and will be stored in pseudonymous format. We do not ask for any information that could identify you personally. This data is collected on behalf of the [...] and will not be passed to third parties. By starting the questionnaire, you agree to the collection of data for the purpose of conducting this study. The processing of your personal data is based on Article 6 (1) DSGVO and §17 DSG NRW. You have the right to revoke your consent to data processing at any time, as well as to request information, correction, restriction of processing and deletion of your personal data. To exercise these rights, please contact the e-mail address mentioned above. The competent supervisory authority is the Data Protection Commissioner of the State of North Rhine-Westphalia.

### Declaration of Consent

Q0: Please confirm that you have read the above terms and conditions and that you are at least 18 years old. [single choice]

- *I hereby confirm that I accept the conditions of participation in this study and that I am at least 18 years old.*

**Demographics** First, we would like to obtain some information about you.

Q\_A: How old are you? [single choice]

- *18-29; 30-39; 40-49; 50-59; 60-69*

Q\_G: What is your gender? [single choice]

- *Female; Male; Non-binary; Describe yourself (free-text answer); Prefer not to answer*

Q\_E: What is your highest level of education? [single choice]

- *No school leaving certificate; Secondary school (primary school) or equivalent leaving certificate; High school (O level) or equivalent leaving certificate; A level, vocational high school / general or university entrance qualification; Occupational or vocational training / apprenticeship; Completion of a technical college or administrative or professional academy; Bachelor's degree; Diploma university course or masters (including: teaching position, state examination, Master's course, artistic or comparable courses of study); PhD; Prefer not to answer*

Q\_K: Do you have practical experience in computer science, computer technology or information technology fields (e. g., through your job or education background)? [single choice]

- *Yes; No; Prefer not to answer*

**General Questions and Experiences with the Coronavirus** First, we would like to ask you some general questions about your smartphone use and your experience with the coronavirus.

Q1: Do you own a smartphone? [single choice]

- *Yes; No*

Q2: [If “Yes” in Q1] Do you use an app (or smartwatch) to monitor your health or track your fitness? [single choice]

- *Yes; No*

Q3: Are you or have you been infected with the coronavirus? [single choice]

- *Yes; No; Prefer not to answer*

Q4: Is there a person in your social circle who is or has been infected with the coronavirus? [single choice]



- *Yes; No; Prefer not to answer*

Q5: How concerned are you that you will become infected with the coronavirus? [single choice]

- *1 – Not concerned; 2 – A-little concerned; 3 – Moderately concerned; 4 – Quite-a-bit concerned; 5 – Very concerned*
- *Prefer not to answer*

Q6: How concerned are you that someone you are close to may be infected with the coronavirus? [single choice]

- *same answer options as Q5*

## 2G-/3G Certificates

Q7: [If “Yes” in Q1] Which of the following COVID-19 apps do you have installed on your smartphone? [multiple choice]

- *Corona-Warn-App; Luca App; CovPass App; CovPass Check App; Other / Additional Corona specific apps (please specify); [exclusive answer] I have not installed any Corona specific app*

Q8: Which type of events or purposes should require a certificate? Please mark the appropriate form of certificate. [matrix table]

- *items: National flights; International flights; National railroad travel; International railroad travel; Crossing countries by car (i. e., outside Germany); Overnight stays in hotels (domestic and abroad); Participation in major events (e. g., soccer matches, concerts); Visits to restaurants, museums, and cinemas; To be allowed to carry out professional activities with public interaction (e. g., hospitals, care facilities); Sport clubs and gyms; Beauty related services (e. g., hairdressing, cosmetics); Private events (e. g., weddings, birthday parties); Retail (clothing stores, construction stores); Stores for daily needs (e. g., grocery stores, pharmacies); Facilities such as schools, daycare centers, and after-school programs; This is an attention check question. Please mark the answer “2G: vaccinated, recovered”*
- *answer options: No certificate should be required; 3G: vaccinated, recovered, or tested (rapid test); 3GPlus: vaccinated, recovered, or tested (PCR test); 2G: vaccinated or recovered; 2GPlus: vaccinated or recovered and additionally tested (rapid test)*

Q9: What variant of certificate would you want to use for the respective purpose? [matrix table]

- *items: same items as Q8 without attention check question*
- *answer options: No certificate should be required; paper-based certificate (e. g., yellow certificate of vaccination , print-out from test center); digital certificate (Corona-Warn-App, CovPass app, or email from test center)*

Q10: Have you already visit events or stores that required proof of vaccination, recovery, or test? [single choice]

- *Yes; No; Don’t know; Prefer not to answer*

Q11: How effortful do you perceive showing proof of vaccination, recovery, or test to be? [single choice]

- *1 – Not effortful; 2 – A-little effortful; 3 – Moderately effortful; 4 – Quite-a-bit effortful; 5 – Very effortful*

Q12: Have you already been vaccinated or recovered against the coronavirus? [single choice]

- *Yes; No; Prefer not to answer*

Q13: [If “Yes” or “Prefer not to answer” in Q12] Which of the following certificates do you typically use to proof your coronavirus vaccination or your recovery, e. g., when visiting a restaurant?

- *Corona-Warn-App; Luca app, Covpass app; Other Corona specific app (please specify); Other digital variant (e. g., email from your doctor; photo of your certificate); Yellow certificate of vaccination; Other paper-based certificate (e. g., print-out from test center); I do not use any of these variants*

Q14: [If “No” or “Prefer not to answer” in Q12] Which of the following certificates do you typically use to proof your coronavirus test, e. g., when visiting a restaurant?

- *Corona-Warn-App; Luca app, Covpass app; Other Corona specific app (please specify); Other digital variant (e. g., email from your doctor; photo of your certificate); Other paper-based certificate (e. g., print-out from test center); I do not use any of these variants*

Q15: [If “[any paper-based variant]” in Q13/Q14] Why do you use a paper-based certificate (instead of a digital variant)? Why did you decide against a digital certificate? [free-text]

Q16: [If “[any digital variant]” in Q13/Q14] Why do you use a digital certificate (instead of a paper-based variant)? Why did you decide against a paper-based certificate? [free-text]

## Certificate Verification Process

- Q17: [If “[any paper-based variant]” in Q13/Q14] Please think about your last control(s) and describe how your paper-based certificate was verified. [free-text]
- Q18: [If “[any digital variant]” in Q13/Q14] Please think about your last control(s) and describe how your digital certificate was verified. [free-text]
- Q19: Please reflect back on the control(s) you just described. How careful did you perceive this control(s) was? [single choice]
- 1 – Not carefully; 2 – A-little carefully; 3 – Moderately carefully; 4 – Quite-a-bit carefully; 5 – Very carefully
  - Prefer not to answer
- Q20: How secure did you feel from an infection by this control(s)? [single choice]
- 1 – Not secure; 2 – A-little secure; 3 – Moderately secure; 4 – Quite-a-bit secure; 5 – Very secure
  - Prefer not to answer
- Q21: How easy do you perceive it is to prove your certificate using an app? [single choice]
- 1 – Not easy; 2 – A-little easy; 3 – Moderately easy; 4 – Quite-a-bit easy; 5 – Very easy
  - I do not use an app for this
- Q22: Please rank the following certificate variants related to their forgery resistance in descending order, i. e., the most forgery-resistant certificate comes in first place. Feel free to place several certificate variants on the same rank or in the same place. [order and rank task]
- items: *Digital certificates with QR-code (e. g., Corona-Warn-App, CovPass app); Yellow certificate of vaccination; Paper-based certificates (e. g., print-out from the test center)*
  - answer options: *Rank 1; Rank 2; Rank 3*
- Q23: Please indicate whether you agree with each of the following statements. [matrix table]
- items: *A photo or screenshot from a QR-code can also be read by a QR code reader; Even without technical devices, you can tell if a QR-code within a corona app is valid; It is harmless to publicly share a photo or screenshot of the QR-code from my corona app; A photo of a QR-code from an app (e. g., Corona-Warn-App) can be photographed and used by an unauthorized person; For a secure verification of digital vaccination certificates, it is sufficient to check the date of the 2nd vaccination within one of the available apps; The validity of a QR code for vaccination certificates (e. g., within the Corona-Warn-App) can be verified with any QR-code reader; QR-codes can only link to websites, they are just differently looking URLs; Correct verification of vaccination certificates is only possible in any case (paper-based or digital) in combination with an ID document; With the Corona apps, it is sufficient to scan the QR-code for a correct check; In the case of the yellow certificate of vaccination, it is sufficient to look for the vaccination date for a correct verification*
  - answer options: *1 – Fully-disagree; 2 – Mainly-disagree; 3 – Neutral; 4 – Mainly-agree; 5 – Fully-agree*
- Q24: What aspects do you think are the most important to verify the digital certificates? What do you think needs to be verified in the case of an app, for example? How can a forgery be detected? In your opinion, what are (technical) security indicators? [free-text]
- Q25: What aspects do you think are the most important to verify the paper-based certificates? What do you think needs to be verified within the yellow certificate of vaccination, for example? How can a forgery be detected? In your opinion, what are security indicators? [free-text]
- Q26: Please drag all the items into the box that are in your opinion necessary for a correct verification of a digital vaccination, recovery, or test certificate consisting of a QR code. Please use the order as you think the verification should proceed. [order and rank task]
- items: *Match ID document, such as ID card, with the displayed personal data within the app used to scan the QR code (e. g., CovPass Check app); Scan QR code with a suitable app, e. g., CovPass Check app; Check manually the date of the 2nd vaccination; Scroll to the 2nd vaccination date within the person’s Corona-Warn-App or CovPass app; Check the person’s Corona-Warn-App pr CovPass app to verify if 2/2 vaccinations are displayed; Match name within the person’s app (or on the person’s document) with an identification document*
  - answer options: *Correct verification consists of*
- Q27: [If “[any paper-based variant]” in Q13/Q14] Please think back to the situations in which you were checked. In what percentage of cases was your paper-based certificate checked professionally, i. e.: the data within the, e. g., yellow certificate of vaccination or on the print-out was verified *and additionally* the data was compared with your ID card? [single choice]
- Please note the slider to your desired position (you can only adjust the slider in steps of 5)
- Q28: [If “[any digital variant]” in Q13/Q14] Please think back to the situations in which you were checked. In what percentage of cases was your digital certificate checked professionally, i. e.: the QR code was scanned, *and additionally* the data was compared with your ID card? [single choice]
- Please note the slider to your desired position (you can only adjust the slider in steps of 5)

## Certificate Inspectors / Verifier

Q29: Have you already personally verified vaccination, recovery, or test certificates (e. g., in the course of performing your job duties)? [single choice]

- *Yes; No*

Q30: [If “Yes” in Q29] In which business area do you work? [single choice]

- *Hotel business; Gastronomy; Body-related services (e. g., hairdressing, cosmetics); artistic sector (e. g., theater, museums), Other (please specify)*

Q31: [If “Yes” in Q29] Please describe how you usually verify vaccination, recovery, or test certificates. [free-text]

Q32: [If “Yes” in Q29] How time-consuming do you perceive conducting these verifications? [free-text]

- *1 – Not effortful; 2 – A-little effortful; 3 – Moderately effortful; 4 – Quite-a-bit effortful; 5 – Very effortful; Prefer not to answer*

## Pandemic Situation

Q33: Please indicate whether you agree with each of the following statements. [matrix table]

- *The 3G rule is contributing in containing the coronavirus pandemic; The 2G rule is contributing in containing the coronavirus pandemic; Contact restrictions are contributing in containing the coronavirus pandemic; School closures are contributing in containing the coronavirus pandemic; Work at home is contributing in containing the coronavirus pandemic; Most people I care about think that coronavirus vaccinations are important to contain the coronavirus pandemic; Vaccination against COVID-19 contributes to the containment of the coronavirus pandemic; Mandatory mask-wearing is contributing in containing the coronavirus pandemic*

## Privacy Disposition

Q34: For each of the following statements, please indicate the extent to which you agree.<sup>2</sup> [matrix table]

- *items: Compared to others, I am more sensitive about the way other people or organizations handle my personal information; Compared to others, I see more importance in keeping personal information private; Compared to others, I am less concerned about potential threats to my personal privacy (R); Compared to others, I value health data as especially worthy of protection*
- *answer options: 1 – Fully-disagree; 2 – Mainly-disagree; 3 – Neutral; 4 – Mainly-agree; 5 – Fully-agree*

Q35: For each of the following statements, please indicate the extent to which you agree.<sup>3</sup> [matrix table]

- *items: I am concerned that the information I submit in a corona app could be misused; I am concerned about submitting information in a corona app, because of what others might do with it; I am concerned about submitting information in a corona app, because it could be used in a way I did not foresee; I am concerned about disclosing health data in a corona app*
- *answer options: 1 – Fully-disagree; 2 – Mainly-disagree; 3 – Neutral; 4 – Mainly-agree; 5 – Fully-agree*

## Demographics (German state)

Q36: In which state do you live? [single choice]

- *Baden-Württemberg; Bavaria; Berlin; Brandenburg; Bremen; Hamburg; Hessen; Mecklenburg Western Pomerania; Lower Saxony; Northrhine-Westphalia; Rhineland Palatinate; Saarland; Saxony; Saxony-Anhalt; Schleswig Holstein; Thuringia*

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<sup>2</sup>The first three items are from the “Disposition to privacy” scale in the version of Yuan Li [22].

<sup>3</sup>The first three items are from the “Perceived Privacy Risk” scale in the version of Chen and Cai [4].

## B Questionnaire – Interviews

*Note: Textparts in red where notes for the interviewers and not necessarily asked during each interview.*

Thanks a lot for agreeing to talk to us. We will note all your answers but keep them anonymous. We will solely document your industry and the position you work in. Are you ok with that?

Q1: Hence the first question: In which position do you work here?

*(Meaning e. g., employee or owner)*

Q2: Under what conditions are guests currently allowed to receive your services or stay with you? Please describe them.

*(If necessary assist mentioning 2G or 3G, etc.)*

Q3: Do you check customers' test, recovery, or immunization records as part of your job?

Q4: What do you estimate is the percentage of paper-based certificates (e. g., yellow immunization card) that you are shown?

Q5: Please think of your current certificate checks or the checks you did during the last few weeks. Please describe how you typically check **paper-based** test, recovery, or immunization records (e. g., yellow immunization card).

*(Follow-up questions, if applicable: How confident are you that your checks are sufficient / "safe"? / How confident do you feel performing it?)*

Q6: What aspects do you think are most important for checking **paper-based** certificates?

*(For example, what do you think needs to be verified in the yellow vaccination card? How can a forgery be detected? What do you think are the security indicators?)*

Q7: Please think of your current certificate checks or the checks you did during the last few weeks. Please describe how you typically check **digital** test, recovery, or immunization records (e. g., in the Corona-Warn-App or CovPass App).

*(Follow-up questions, if applicable: How confident are you that your checks are sufficient / "safe"? / How confident do you feel performing it?)*

Q8: What aspects do you think are most important for checking **digital** certificates?

*(For example, what do you think needs to be verified in the yellow vaccination card? How can a forgery be detected? What do you think are the security indicators?)*

*The following three questions were asked separately for paper-based and digital certificates.*

Q9: On a scale from 1 - not sure to 5 - very sure: How sure are you to recognize forged certificates?

*(Follow-up question: Have you ever recognized a forgery before? If so, how?)*

Q10: On a scale from 1 - not time-consuming to 5 - very time-consuming. How time-consuming do you perceive the certificate checks to be?

Q11: On a scale from 1 - not thoroughly to 5 - very thoroughly, how thoroughly do you think you execute your checks?

Q12: Thinking about the last few weeks, did you have more positive or negative experiences with checking test, recovery, or immunization records?

*(e. g., sympathetic guests; Would you like to tell us/myself about those experiences?)*

Q13: Do you feel adequately informed by politics (or your managers) about how to correctly check the various certificates?

*(Have you been trained on how to check certificates?)*

Q14: Would you have hoped for (more) education, support, or information from politics (or you managers or associations, e. g., Dehoga)?

*(What kind of education, support, and/or information would you have wished for?)*

Q15: Do you have any concerns regarding the verification of the different certificates?

*(Difficulties e. g., to detect forgeries, scaring away guests, etc.)*

Q16: Would you like to tell us anything else?

Thanks a lot for your time and our discussion!