COVID-19 Vaccination Willingness: Investigating the Predictors Pre- and Post-Vaccination Start in Germany

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Keywords: COVID-19, vaccination, vaccine willingness, vaccine hesitancy, health communication

Acknowledgements

Funding: This work was funded by the Germany Federal Ministry of Education and Research (BMBF) under the grant agreement 01KI20500.

Data Availability Statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found below: https://zenodo.org/record/4590017 and https://zenodo.org/record/4946140.

Introduction

For many, vaccines are a desperately needed ray of hope in this midst of the COVID-19 pandemic. However, voluntary immunisation can only be effective if a large proportion of the population is

willing to take the vaccine. This vaccination willingness is shaped by publics' attitudes towards the vaccines. Attitudes play a central role in people's everyday lives and are typically built on previous experiences and memory processes. However, when people are confronted with a new object, like a new vaccine, they are also able to immediately construct attitudes towards the unfamiliar object (Fazio, 2007; Schwarz, 2007). Those "spontaneous" attitudes are based on available affective and cognitive associations, and are influenced by social and contextual factors (e.g., Stern et al., 1995; van Giesen et al., 2015). Thus, one crucial step in fighting the pandemic is understanding the factors influencing attitudes towards the newly developed COVID-19 vaccines.

Factors Influencing Vaccination Willingness

Anti-vaccine attitudes have existed since vaccinations were first administered. In Germany, intense debates about vaccines have taken place since the middle of the 19th century, when a mandatory smallpox vaccination for children was first introduced (Meyer & Reiter, 2004). However, as there is no compulsory vaccination in Germany today (with exception of measles for children and community or health care staff), the "power of the state" with regard to vaccinations is less prominent than in countries with more mandatory vaccinations (e.g., Italy and France).

Vaccine hesitancy is typically more widespread than the anti-vaxxer movement represented by a small but loud minority in a population. Vaccine hesitancy is a complex and context-specific phenomenon involving multiple factors (Harrison & Wu, 2020), such as complacency, convenience, and confidence (MacDonald & Hesitancy, 2015). Complacency includes the perceived personal risk of getting infected and becoming very sick from the disease: Where risk perception is low, vaccination hesitancy increases (Dror et al., 2020; Gilles et al., 2011; Mesch & Schwirian, 2019). Convenience then describes the ease by which the vaccine can be

obtained. Finally, confidence highlights trust in the vaccine and vaccination process, which numerous studies have shown to be key (Gilles et al., 2011; Lyons, 2014; Mesch & Schwirian, 2019; Murphy et al., 2021; Skjefte et al., 2021; Taylor et al., 2020; van Dijck & Alinejad, 2020).

Trust can relate to the context of the government, the pharmaceutical industry, scientific experts, or the vaccine itself. A Swiss longitudinal study found that trust in medical organisations, not trust in the government, significantly predicted people's vaccination status (Gilles et al., 2011). In contrast, vaccination programmes in low- and middle-income countries often fail due to low trust in government (Larson, 2020). Hearing reports about the high efficacy in early vaccine candidates (Mega, 2021), others sharing their vaccination experience and increased knowledge about the vaccines can, however, enhance trust in the vaccine and reduce conspiracy beliefs (Hornsey et al., 2018; Lyons, 2014; Mesch & Schwirian, 2019; Murphy et al., 2021; van Dijck & Alinejad, 2020). On the other hand, conspiracy beliefs or a mindset that is characterised by hyper scepticism decreases willingness to be vaccinated (Hornsey et al., 2018; Lyons, 2014; Murphy et al., 2021; Rossen et al., 2019; van Dijck & Alinejad, 2020), while the freedom to decide for oneself or for one's children increases it (Harrison & Wu, 2020; Hornsey et al., 2018; Lyons, 2014; Rossen et al., 2019).

Current Research on COVID-19 Vaccination Willingness

The current COVID-19 pandemic is characterised by a number of unique factors that have the potential to challenge the validity of the above-mentioned predictors of vaccination willingness. Firstly, the COVID-19 vaccines were developed and approved faster than ever before (Ball, 2021). For many, the rapid development of the vaccine gives rise to scepticism about both the immediate risks it poses and its possible long-term effects (Dror et al., 2020; Taylor et al., 2020). Secondly, the current pandemic has almost overnight transformed politics, the economy, and people's

everyday life around the world. The global effort to fight the virus - often represented, organised, and communicated by political decision makers - has led to tensions between individual autonomy and state power. In Germany, as well as in other countries, this spilled over into e.g., anti-lockdown protests (e.g., Lange & Monscheuer, 2021) or "anti-hygienic" demonstrations in Germany (e.g., Vieten, 2020).

So far, all published articles reporting predictors of COVID-19 vaccination willingness have collected most of their data pre-vaccination start: Hitherto, trust (Murphy et al., 2021; Taylor et al., 2020), conspiracy beliefs (Murphy et al., 2021), information behaviour (Murphy et al., 2021), influenza vaccination status (Dror et al., 2020) and age (Murphy et al., 2021), have been reported as significant predictors of COVID-19 vaccination willingness. Furthermore, men seem to express higher COVID-19 vaccination willingness than women, as a meta-analysis by Zintel et al. (2021) shows. In the USA, Fridman et al. (2021) conducted a longitudinal study on COVID-19 vaccine willingness months before the start of mass vaccination and found political affiliation to be the main predictor of vaccination willingness, where a decrease among self-affiliated Republicans was observed, compared to a slight increase among Democrats.

Purpose of this Study

Research has already established that the general willingness to get vaccinated has increased in Germany post-vaccination start (e.g., COSMO, 2021; CovidDataHub, 2020). This paper tries to contribute to the growing literature on predictors of COVID-19 vaccination willingness.

Moreover, the current pandemic presents a methodological opportunity to closely study vaccination willingness pre- and post-vaccination start. While in situations of limited knowledge people rely more heavily on affective object linkages (e.g., van Giesen et al., 2015), cognitive associations become stronger over time when more information is available. It is therefore possible

that predictors of COVID-19 vaccine hesitancy do not equally apply pre- and post-vaccination start. To the authors' knowledge, there is no literature systematically comparing the predictors of vaccination willingness pre- and post-vaccination start within the same sample. We therefore aim to answer the following research questions:

1. Do established predictors of general vaccination willingness also apply in the context of the newly developed COVID-19 vaccines pre-vaccination start?
2. Do the predictors of COVID-19 vaccination willingness change post-vaccination start?

The research questions were investigated using two linked national surveys. In this paper, the pre-vaccination start survey will be referred to as "Wave 1" and the post-vaccination start survey will be referred to as "Wave 2". Each research question was addressed with an independent analysis, hence the segmentation of this paper into "Study 1" and "Study 2". The overall study protocol was approved by the Ethics Committee of the Sigmund Freud University.

Study 1

Methods

Sampling and Data Management

This study was conducted with a national survey of the German population aged 16 and over, employing relevant items examining vaccination willingness. This was done from 30 October 2020 to 14 December 2020 in Germany as part of the *Viral Communication* project (viralcomm.info).

Respondents were recruited by sending postcard invitations to a random selection of 30,000 households, using the German postal service's (Deutsche Post) address database. Addresses were stratified based initially on relative population size across federal states in Germany (DESTATIS,

2020). Following data collection, survey data was cleaned and prepared for analysis, with the application of a range of inclusion criteria. Valid cases needed to include responses for *age group*, *sex*, *nationality group* (German/other), *migration background, federal state*, *highest school leaving qualification*, and *highest professional qualification*. These criteria were strictly required as weighting was applied next, using the latest available German census results (Zensus 2011, 2011). All weighting questions were exactly aligned with the census.

In total, 1,480 survey entries were registered. 417 respondents were excluded for not fitting the inclusion criteria, leaving a total $N = 1{,}063$ respondents ($\hat{p}_{woman} = 53\%$, $M_{age} = 48.9$, $SD = 18.6$ [weighted]), of which a total of $n = 936$ responded to the vaccination item in question.

Data Analysis

In order to ascertain the baseline predictors for COVID-19 vaccination willingness, correlation analyses and independence tests were performed with the following independent variables: Socio-demographic characteristics, trust in different COVID-19 information sources, voting behaviour/intentions and self-assessment of COVID-19 risk. Due to the ordinal nature of the dependent variable, Kendall's Tau-b and -c were used to identify non-parametric correlations with other ordinal or interval variables. Kruskall-Wallis and corresponding post-hoc tests with Bonferroni correction were used for nominal independent variables. Compound variables for attitudes towards science, trust in scientific actors, trust in governmental actors and conspiracy-mindedness were computed for each respondent by taking the average of the relevant (and responded-to) items.

Throughout this paper, the threshold for reporting a result as statistically significant is $\alpha < .05$. Two-sided tests were performed. Only noteworthy results were reported, exhibiting at least moderate effect sizes or which are notably non-significant or small in effect size.

Results

Among the socio-demographic variables, age was identified as a predictor for vaccination willingness. Although the correlation between age and vaccination willingness was rather weak overall, $r_\tau = .27$, $p < .001$, there were major differences in vaccine willingness between specific age bands at the bottom and top of the adult age distribution, $H\,(7) = 114.022$, $p < .001$, $\eta^2 = .13$ (13% of variance explained). The largest differences were apparent between the age groups 20-29 and 70+, $z = 9.832$, $p < .001$, $\eta^2 = .33$ (33% of variance explained). People aged 20-29 were most disinclined to be vaccinated against COVID-19: Almost half of this age band (viz., 48%), 95% CI [.40, .56], were "Definitely not" or "Probably not" willing to vaccinate. In contrast, 92% of people aged 70+, 95% CI [.84, .94], would have "Probably" or "Definitely" vaccinated against COVID-19.

At the overall level, there were statistically small differences between respondents with different professional qualifications, $H\,(7) = 36.634$, $p < .001$, $\eta^2 = .04$ (4% of variance explained). Most notably, however, people who graduated from university, academic college or art college were moderately less likely to vaccinate against COVID-19 compared to people with a degree from a university of applied sciences, $z = 4.043$, $p = .001$, $\eta^2 = .11$ (11% of variance explained). Vaccination willingness among people with no professional qualification was also lower than among those with a degree from a university of applied sciences, $z = 5.015$, $p < .001$, $\eta^2 = .08$ (8% of variance explained). There were no significant differences in vaccination willingness between women and men, $U = 82{,}139.500$, $p = .059$.

While people's self-reported political orientation was only very weakly negatively correlated with vaccination willingness, $r_\tau = -.14$, $p < .001$, there were major differences between the political parties they would vote for in the next national parliamentary election, $H\,(5) = 93.178$,

$p < .001$, $\eta^2 = .18$ (18% variance explained). Here, the AfD scored lowest in COVID-19 vaccination willingness, *Mdn* = 1 "Definitely not" and therefore exhibited strong differences in comparison with the CDU/CSU, $z = 8.553$, $p < .001$, $\eta^2 = .26$ (26% variance explained), the FDP, $z = 4.650$, $p < .001$, $\eta^2 = .27$ (27% of variance explained), the Bündnis90/Die Grünen, $z = 7.229$, $p < .001$, $\eta^2 = .28$ (28% of variance explained), the SPD, $z = 6.201$, $p < .001$, $\eta^2 = .30$ (30% variance explained), and most strongly, Die Linke, $z = 8.657$, $p < .001$, $\eta^2 = .72$ (72% of variance explained).

Some effects related to information behaviour were observed as well. There were significant differences in whether people in Germany were willing to vaccinate against COVID-19 between the means with which they accessed their primary news source on the pandemic situation, χ^2 (12) = 89.046, $p < .001$, $V = .14$ (2% of variance explained). Here, people who used social media were significantly less likely to vaccinate compared to those who used television, $p < .001$, radio, $p < .001$, print newspaper, $p < .001$, or mobile apps, $p < .001$. When it came to differences between social media platforms, χ^2 (12) = 90.335, $p < .001$, $V = .20$ (4% of variance explained), Facebook-users were significantly more likely to reject the vaccine, $p = .011$, and people who did not use social media were more likely to vaccinate than those using Facebook, $p < .001$; WhatsApp, Threema or Telegram, $p = .002$; YouTube, $p = .001$; and Instagram, $p < .001$.

Trust in relevant governmental and scientific actors as reliable sources of information on COVID-19 was also an important factor as there were moderate positive correlations with trust in governmental actors, $r_\tau = .36$, $p < .001$ (13% of variance explained), and scientific actors, $r_\tau = .39$, $p < .001$ (15% variance explained). It was also found that vaccination willingness negatively correlated with anger over the COVID-19 regulations, $r_\tau = -.30$, $p < .001$ (9% of variance explained).

There were significant moderate differences in vaccination willingness between people who considered themselves to be at high risk of developing serious health complications from COVID-19 and those who did not, $U = 30335.000$, $p < .001$, $\eta^2 = .11$ (11% of variance explained). This effect size dropped significantly, $z = 2.876$, $p = .004$, when it came to whether they considered someone else in their household to be at risk, $U = 42{,}470.000$, $p < .001$, $\eta^2 = .03$ (3% of variance explained). We additionally examined the relationship between age and personal risk perception as a potential mediator for the age trend described above. Indeed, the odds of perceiving oneself to be at high risk of developing serious health issues from COVID-19 increased by the factor of 1.05 for each increment in age, $B = 0.049$, $SE = 0.005$, $Wald = 99.941$, $p < .001$, Exp (B) = 1.050, 95% CI [1.040, 1.060].

People who had gotten the Flu vaccine within the last nine months were far more likely to vaccinate against COVID-19 than those who had not, $U = 25{,}742.000$, $p < .001$, $\eta^2 = .28$ (28% of variance explained). COVID-19 vaccination willingness was additionally strongly positively correlated with the willingness to vaccinate against the Flu, $r_\tau = .61$, $p < .001$ (37% of variance explained).

Table 1. Correlation matrix showing ordinal predictors of COVID-19 vaccination willingness (Wave 1).

Kendall's tau		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	COVID-19 vaccination willingness	1.00													
2	Age	.27**	1.00												
3	Science Attitudes	.30**	.09**	1.00											
4	Concern over own health	.28**	.20**	.19**	1.00										
5	Anger over Corona regulations	-.30**	-.13**	-.29**	-.36**	1.00									
6	Trust in Angela Merkel	.35**	-.02	.34**	.24**	-.38**	1.00								
7	Trust in Christian Drosten	.41**	.10**	.41**	.14**	-.42**	.58**	1.00							
8	Trust in Jens Spahn	.33**	.06	.43**	.19**	-.42**	.71**	.62**	1.00						
9	Trust in German Public Health Ministry	.36**	.02	.47**	.22**	-.35**	.67**	.64**	.77**	1.00					
10	Trust in WHO	.28**	.09**	.29**	.25**	-.29**	.47**	.55**	.51**	.62**	1.00				
11	Trust in state government	.32**	.02	.30**	.20**	-.38**	.60**	.58**	.62**	.63**	.53**	1.00			
12	Trust in Robert Koch Institute	.37**	.08**	.36**	.26**	-.41**	.64**	.76**	.64**	.66**	.66**	.63**	1.00		
13	Frequency in accessing Twitter	-.44**	.23*	-.17	.54**	-.12	.30**	-.08	.23*	.05*	.23	.29**	.34**	1.00	
14	Conspiracy mindedness	-.27**	-.07**	-.27**	-.06*	.29**	-.40**	-.38**	-.39**	-.38**	-.34**	-.26**	-.40**	.48**	1.00

**. Correlation is significant at the .01 level (2-tailed).

*. Correlation is significant at the .05 level (2-tailed).

Table 2. Summary of noteworthy Mann-Whitney U tests for binary predictors of COVID-19 vaccination willingness (Wave 1).

	U	*z*	*p*	η^2
Perceived personal risk	30335.000	8.160	.000	.11
Perceived risk of household member	42470.000	4.440	.000	.03
Flu Vaccine in last 9 months	25742.000	14.951	.000	.28

Table 3. Summary of noteworthy Kruskal-Wallis tests and post-hoc pairwise comparisons for non-binary nominal predictors of COVID-19 vaccination willingness (Wave 1).

	H	*df*	*p*[a]	η²	*z*
Age Group	114.022	6	.000	.13	
15 - 19 vs. 70+			.000	.16	4.941
20 - 29 vs. 50 - 59			.000	.13	6.324
20 - 29 vs. 60 - 69			.000	.12	5.806
20 - 29 vs. 70+			.000	.33	9.832
30 - 39 vs. 70+			.000	.11	5.640
40 - 49 vs. 70+			.000	.14	6.722
Personal Qualification	36.634	5	.000	.04	
University, Academic College vs. University of Applied Sciences			.001	.11	4.043
No Professional Qualification vs. University of Applied Sciences			.000	.08	5.015
Technical college degree vs. University of Applied Sciences			.008	.07	3.450
Political Affiliation	93.178	5	.000	.18	
AfD vs. SPD			.000	.30	6.201
AfD vs. FDP			.000	.27	4.650
AfD vs. Bündnis90/Die Grünen			.000	.28	7.229
AfD vs. CDU/CSU			.000	.26	8.553
AfD vs. Die Linke			.000	.72	8.657
SPD vs. Die Linke			.018	.09	3.237

a. For pairwise comparisons, significance values have been adjusted by the Bonferroni correction for multiple tests

Discussion

In accordance with previous research on vaccination willingness, we found that high trust in scientific and governmental actors, risk perception, positive attitudes towards science, influenza vaccination status and social media usage positively predicted vaccination willingness for the COVID-19 vaccine. The strongest relationship was found between the influenza vaccination status and the willingness to get the COVID-19 vaccine. General conspiracy mindedness, the belief in a vaccination conspiracy theory, as well as anger over the Corona regulations negatively predicted vaccination willingness. With some exceptions (i.e., trust in governmental actors and age being more relevant), our results prove that established predictors of vaccination willingness also hold true in the context of the COVID-19 (pre-vaccination start).

In line with the work by Murphy et al. (2021), we showed that people who used social media as means of accessing information about the pandemic were significantly more likely to reject the COVID-19 vaccine. This might be due to the influence of social media as a driver of misinformation as a result of self-reinforcing echo-chambers (Del Vicario et al., 2016). The number of Facebook-users rejecting the vaccine particularly stood out, meaning that anti-vaccination content could be spreading particularly effectively on this platform.

In contrast to the findings by Gilles et al. (2011), we found trust in governmental and scientific actors to be equally important in the context of the newly developed vaccine in Germany. The COVID-19 vaccine being a highly political topic with German politicians actively promoting the vaccine, trust in governmental actors seems to be especially relevant in this context.

Secondly, in contrast to previous research (Hornsey et al., 2018), age was found to be a major predictor in the case of COVID-19. This finding is possibly unique for this disease, considering the increasing risk of serious health issues with increasing age. In fact, we found a significant relationship between age and perceived personal risk of developing serious health issues from COVID-19. This is supported by research indicating that higher vaccination intentions are predicted by a higher perceived risk of COVID-19 (Glöckner et al., 2020; Malik et al., 2020).

An additional predictor was individuals' political affiliation. People who would have voted for the far-right party AfD in a national election were far more likely to be vaccine hesitant. However, this might not fully be due to their political views, as the weak correlation with political orientation showed. This could rather be a result of categorical opposition to the status quo, a lack of trust, and unconventional/alternative views and mindsets: Niedermayer and Hofrichter (2016) have pointed out that the majority of AfD-voters do not exhibit extremist far-right views and that this constituency consists of diverse socio-demographic groups which tend not to not trust the

more established parties and which tend to vote for an alternative party as a form of protest (Pickel, 2019).

There was no significant relationship between gender and vaccination willingness. This study can therefore not confirm the findings of other works (see Zintel et al., 2021), at least when it comes to the German context.

Study 2

Methods

Sampling and Data Management

Upon completion of the Wave 1 survey, respondents were invited to remain on the project's contact list to participate in a follow-up survey (Wave 2) approximately three months later. Thus, the Wave 2 survey conducted between 2 March 2021 and 22 March 2021 was only completed by a subset of Wave 1 respondents who accepted the invitation. The Wave 1 and Wave 2 datasets were merged while only retaining entries from respondents who participated in both surveys. The same inclusion criteria as in Study 1 were applied in order to subsequently weight according to the latest census distributions (Zensus 2011, 2011). The final sample size was $N = 484$ ($\hat{p}_{woman} = 51\%$, $M_{age} = 48.2$, $SD = 17.9$ [weighted]), of which $n = 407$ responded to the vaccination item both in Wave 1 and Wave 2. It must be noted that this subsample is likely not fully representative of the population due to the self-selective nature of the subsampling approach.

Data Analysis

The same correlation analyses and independence tests as in Study 1 were conducted for Wave 1 and Wave 2 in order to perform a repeated measures analysis. The comparisons between the Wave 1 and Wave 2 surveys themselves involved identifying significant differences in effect sizes by

converting *r*-coefficients into *z*-scores (Fisher's z-transformation) and subsequently performing *z*-tests. Additionally, Wilcoxon sign-rank tests were performed to assess the degree to which vaccination willingness, trust in governmental actors and anger over COVID-19 regulations changed between Wave 1 and Wave 2.

It is important to note that due to the smaller and more selective sample in this study, there were inconsistencies between the identified Wave 1 predictors in Study 1 (representative sample) and Study 2 (limited subsample). The mismatches were related to the following independent variables: *political orientation*, *frequency of accessing Instagram*, *frequency of accessing Twitter*, and *school leaving qualification*. To minimise type I and type II errors, the repeated measures analysis only included trends whose Wave 1 results matched the representative cross-sectional analysis (Study 1) in their significance (i.e., whether they were both significant or not). This means that trends involving the independent variables mentioned above were excluded.

Results

Trends in COVID-19 Vaccine Willingness and Attitudes towards the Government

Before mass vaccination for COVID-19 began in Germany at the end of 2020, over half of the population was willing to get vaccinated, 95% CI [.56, .66]. In March 2021, this number significantly increased to three quarters of the population, 95% CI [.71, .80]. Inversely, rejection of the vaccine declined from about one quarter, 95% CI [.22, .31] to around one tenth, 95% CI [.09, .15]. A Wilcoxon sign-rank test shows that the increase in vaccine willingness amounted to an overall large difference between both measurement points, $z = 7.007$, $p < .001$, $\eta^2 = .15$ (15% of variance explained).

At the same time, trust in governmental actors decreased greatly, $z = -9.691$, $p < .001$, $\eta^2 = .27$ (27% of variance explained). This decline in trust was particularly evident for Angela Merkel,

z = -7.489, p < .001, η^2 = .16, and Jens Spahn, z = -9.640, p < .001, η^2 = .27 (27% of variance explained). Trust in prominent German virologist Christian Drosten and the WHO did not change significantly, z = -0.374, p = .709, and z = -1.551, p = .121. We also observed a strong increase in anger over the COVID-19 regulations, z = 8.842, p < .001, η^2 = .21 (21% of variance explained).

Shifting Predictors for COVID-19 Vaccine Willingness

We found important changes in the predictors of vaccine willingness following the onset of mass vaccination in Germany. Table 4, Table 5 and Table 6 provide an overview of the independent variables and their development from Wave 1 to Wave 2.

The differences in vaccination willingness between age groups were subject to some change over time: The Kruskal-Wallis pairwise comparison for this variable showed that the gap between the age groups 16-19 and 70+ which was significant in Wave 1, z = 3.857, p = .002, was not significant in Wave 2, z = 3.032, p = .051. The same applied to the differences between people aged 50-59 and 70+, z = 3.098, p < .041 vs. z = 2.111, p = .731. The effect size inherent in the difference between age group 30-39 and 70+ significantly diminished over time, z = -4.158, p < .001, from z = 8.830, p < .001, η^2 = .67 (67% of variance explained) to z = 5.096, p < .001, η^2 = .26 (26% of variance explained).

The effects of whether people had the German nationality or not were not significant in Wave 1, U = 2,263.000, p = .374, but they were significant in Wave 2, U = 2,263.000, p < .001, η^2 = .04 (4% of variance explained). Similarly, whether people had a migration background did not have a significant effect on vaccination willingness at first, U = 7,655.500, p = 361, while there was a significant moderate difference in Wave 2, U = 4,745.500, p < .001, η^2 = .10 (10% of variance explained). German residents with a foreign nationality or with a migration background were less likely to be willing to vaccinate against COVID-19.

There were some differences in the pairwise comparisons for professional qualification, although the overall effect inherent in the Kruskall-Wallis test did not differ significantly, z = 0.896, p = .370. The significant difference between people without a professional qualification and those with a degree from a university of applied sciences, z = 3.602, p = .005, η^2 = .11 (11% of variance explained), became non-significant in the second survey, z = 2.761, p = .086.

The effects of political affiliation changed dramatically. The differences between people who would vote for the AfD and those who would vote for the Bündnis90/Die Grünen increased significantly, z = 3.153, p = .002, from z = 4.980, p < .001, η^2 = .27 (27% of variance explained) to z = 6.621, p < .001, η^2 = .64 (64% of variance explained). The difference between AfD and die Linke increased significantly as well, z = 13.767, p < .001, from z = 3.990, p = .001, η^2 = .27 (27% of variance explained) to z = 6.390, p < .001, η^2 = .99 (99% of variance explained).

The influence of one's self-perception as a person at risk of developing serious health issues did not change over time, z = 1.329, p = .184. However, the effect based on the perception of whether *someone else* in the same household was at risk changed from significant, U = 7,379.500, p < .001, η^2 = .28 (28% of variance explained), to non-significant, U = 9,374.000, p = .463.

On the other hand, the correlation between COVID-19 vaccine willingness with people's trust in some scientific and governmental actors increased. This included Christian Drosten, z = 2.275, p = .023, from r_τ = .14, p = .001 (2% of variance explained) to r_τ = .31, p < .001 (10% of variance explained); the WHO, z = 2.706, p = .007, from r_τ = -.10, p = .028 (1% of variance explained) to r_τ = .11, p = .021 (1% of variance explained); and the respective state government, z = 2.200, p = .023, from r_τ = .09, p = .041 (1% of variance explained) to r_τ = .25, p < .001 (6% of variance explained).

Table 4. Overview of COVID-19 vaccination willingness predictors and their development over time based on Kendall's tau-b and -c. The Study 1 column presents the representative results, while the other columns show the Wave 1 and Wave 2 comparisons.

Kendall's tau	*r*			*z*
	Study 1	Study 2		
	Wave 1	Wave 1	Wave 2	Wave 1-Wave 2
Age	.27**	.31**	.25**	-0.927
Attitudes towards Science	.30**	.21**	.12**	-1.398
Concern over own Health	.28**	.19**	.23**	0.538
Anger over Corona Regulations	-.30**	-.13**	-.12**	0.203
Conspiracy Mindedness	-.27**	-.24**	-.32**	-1.122
Belief in Vaccination Conspiracy	-.32**	-.11**	-.21**	-1.359
Trust in Scientific Actors	.39**	.16**	.22**	0.876
Trust in Governmental Actors	.36**	.19**	.21**	0.172
Trust in Angela Merkel	.35**	.11*	.17**	0.814
Trust in Christian Drosten	.41**	.14*	.31**	2.275*
Trust in Jens Spahn	.33**	.12**	.26**	1.918
Trust in Federal Health Ministry	.36**	.14**	.10*	0.515
Trust in WHO	.28**	-.10*	.11*	2.706*
Trust in State Government	.32**	.09*	.25**	2.200*
Trust in RKI	.37**	.15*	.20**	0.662

**. Effect is significant at the .01 level.

*. Effect is significant at the .05 level.

Table 5. Overview of COVID-19 vaccination willingness predictors and their development over time based on Mann-Whitney U tests. The Study 1 column presents the representative results, while the other columns show the Wave 1 and Wave 2 comparisons.

Mann-Whitney U	η^2			*z*
	Study 1	Study 2		
	Wave 1	Wave 1	Wave 2	Wave 1-Wave 2
Nationality Group	.00	.00	.04**	
Migration Status	.00	.01	.10**	
Perceived personal risk	.11**	.22**	.14**	1.329
Perceived risk of household member	.03**	.08**	.00	
Flu Vaccine in last 9 months	.28**	.22**	.14**	1.469

**. Effect is significant at the .01 level.

*. Effect is significant at the .05 level.

Table 6. Overview of COVID-19 vaccination willingness predictors and their development over time based on Kruskal-Wallis H tests. The Study 1 column presents the representative results, while the other columns show the Wave 1 and Wave 2 comparisons.

Kruskal-Wallis H	η^2			*z*
	Study 1	Study 2		
	Wave 1	Wave 1	Wave 2	Wave 1-Wave 2
Age Group	.13**	.24**	.16**	-1.525
16-19 vs. 70+	.16**	.18**	.14	
20-29 vs. 70+	.33**	.29**	.47*	1.655
30-39 vs. 70+	.11**	.67**	.26**	-4.158**
40-49 vs. 70+	.14**	.14**	.12**	-0.190
50-59 vs. 70+	.04**	.08*	.04	
60-69 vs. 70+	.04**	.19**	.13**	-0.671
Professional Qualification	.04**	.07**	.04**	-0.896
No Professional Qualification vs. University of Applied Sciences	.08**	.11**	.06	
Political Affiliation	.18**	.47**	.50**	0.378
AfD vs. Bündnis90/Die Grünen	.28**	.27**	.64**	3.153**
AfD vs. Die Linke	.72**	.27**	.99**	13.767**
AfD vs. CDU/CSU	.26**	.30**	.33**	0.299

**. Effect is significant at the .01 level.
*. Effect is significant at the .05 level.

Discussion

Shifting Predictors of COVID-19 Vaccination Willingness (Pre- and Post-Vaccination Start)

We observed interesting patterns when looking at how predictors of COVID-19 vaccination willingness change pre- and post-vaccination start. On the one hand, some of the predictors turned from being significant pre-vaccination start to not being significant post-vaccination start. On the other hand, we observed variables shifting from a non-significant to a significant relationship with COVID-19 vaccination willingness post-vaccination start, as well as significant changes in effect size.

Overall, the effect of age as a predictor for vaccination willingness somewhat diminished over time when looking at specific age group comparisons. This can be explained by the general increase in vaccination willingness which reduced the differences between these age groups. As

previously mentioned, people rely more heavily on affective object linkages (e.g., van Giesen et al., 2015) in situations where knowledge is limited, while cognitive associations become stronger over time when more information is available. Early on, vaccination willingness was significantly higher for older age groups that also faced a higher risk of developing severe symptoms. As an affective association, this fear might have driven vaccination willingness pre-vaccination start among older generations, while vaccination willingness in younger people increased later on, when more information became available. Nevertheless, the magnitude of variation among age groups did not decrease significantly, and the overall trend towards higher vaccination willingness with increasing age remained with the notable exception of 16- to 19-year-olds.

The differences between the AfD and left-wing political parties such as the Bündnis90/Die Grünen and Die Linke increased over time, indicating a polarisation in vaccination willingness between people affiliated with more established parties and the right-wing AfD. A cause of this could be the self-reinforcing echo-chambers as people who vote for the AfD also tend to have more deeply rooted alternative views and a higher conspiracy mindedness. This is supported by Flew's (2019) argument that misinformation as the result of a larger trust crisis is additionally fuelled by these echo-chambers. Intentions to vaccinate can be influenced by misinformation (Jolley & Douglas, 2014) and conspiracy beliefs (Blaskiewicz, 2013; Hornsey et al., 2018); this has been shown to apply in the COVID-19 context as well (Bertin et al., 2020; Čavojová et al., 2020; Jensen et al., 2021). Our German findings show parallels with evidence from the USA indicating polarisation between Republicans and Democrats on the issue of COVID-19 vaccination over time (Fridman et al., 2021).

The correlation with trust in Christian Drosten, the WHO and the state government saw a significant increase in effect size, indicating that the trust as a mediator for vaccination willingness has become more important.

Ultimately, nationality and migration status emerged as unexpected predictors as vaccination willingness seems to have increased at a slower rate for people with a foreign nationality or a migration background. Further research would be needed to identify the reasons for this difference, but regardless, German residents with a foreign nationality or with a migration background were generally less willing to get vaccinated against COVID-19. This could be due to language barriers, certain information behaviours, religious factors, or a higher susceptibility to misinformation about vaccines. This is an especially important finding since new infections among migrants tend to be higher than among non-migrants in Germany, e.g., due to cramped living conditions (Hintermeier et al., 2021).

Conclusion

Limitations

From the survey items employed in both studies, the increase in COVID-19 vaccination willingness could not be explained sufficiently. One factor responsible for this increase might be that the vaccine is seen as a means to end the long period of regulations. Although the positive correlation with trust in governmental actors did not generally change significantly over time, vaccination willingness increased while trust in governmental actors decreased. However, a change in the negative correlation with anger over the regulations could not be confirmed, possibly due to the limited subsample (Study 2). Other factors which could be explored in future research (perhaps more qualitative) are people's explicit reasoning for getting or not getting the vaccine,

proximity to people who have been vaccinated, increased knowledge about the vaccine(s), the benefits that might come with immunisation, as well as that vaccination against COVID-19 evolved from a hypothetical scenario to reality.

Implications

Our studies were able to show the applicability of most established predictors of vaccine hesitancy to the COVID-19 context, but not all of those predictors are stable over time. The results suggest that timely and evidence-based communication campaigns are needed to increase vaccination willingness in a general manner. In order to counter effects based on certain socio-demographics, specific communication endeavours also need to be targeted at groups which either have lower willingness from the start or those which are likely to "fall behind" in the future. This is particularly important as some of these groups could be marginalised communities which would otherwise experience more tenuous health situations and subsequently increased social inequality.

Finally, trust is a pivotal factor in science communication and crisis management (see Borchelt & Nielsen, 2014; Guenther & Weingart, 2016; Nisbet & Scheufele, 2009; Siegrist et al., 2007; Siegrist & Zingg, 2014). This also holds true in the context of vaccination willingness (Gilles et al., 2011; Lyons, 2014; Mesch & Schwirian, 2019; Murphy et al., 2021; Skjefte et al., 2021; Taylor et al., 2020; van Dijck & Alinejad, 2020), and specifically when it comes to COVID-19 vaccination, as this study's results show. This work provides yet more evidence for the importance of long-term communication led by scientific stakeholders, aimed at building relationships of trust with diverse publics. Trust in political actors also arose as an important factor in the context of COVID-19. This indicates that future evidence-based management of highly politicised issues and crises (e.g., Jensen, 2020; Jensen & Gerber, 2020) could be enhanced with a public affairs and political communication agenda which increasingly focuses on fostering trust among publics.

All authors attest they meet the ICMJE criteria for authorship.

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Appendix A: Survey Design

For each of the survey items described below, respondents were given "Unsure" and/or "Prefer not to say" as a response option. Likert-type and semantic differential items included a "Not applicable / No Opinion" response option.

Vaccination Willingness

For the section on voluntary vaccination, the question "Would you take the following measures on a voluntary basis?" was followed by the item "Coronavirus (COVID-19) vaccination." Respondents were able to answer by means of a 5-point Likert-type scale including the options "Definitely not," "Probably not," "Maybe," "Probably" and "Definitely". Respondents were also asked to indicate whether or not they had gotten vaccinated against influenza in the last nine months.

Socio-demographics

Respondents were asked to indicate their age, gender, nationality, migration background, state of residence, education, professional qualification, working situation, occupation, and political orientation (on a scale from -3 = far left until +3 = far right). They were also asked about their political affiliation with the question: "Which political party would you vote for if there was a national election held today?".

Trust in Political and Scientific Actors

To measure trust in key institutional sources of information on the pandemic (i.e., RKI, WHO, respective state government, German Public Health Ministry, German health minister Jens Spahn, German virologist Christian Drosten and Angela Merkel), respondents were asked to rate their

level of trust on a 5-point Likert-type scale, ranging from "Completely distrust" to "Completely trust," with "Neutral" as the midpoint.

A different item asked respondents to rate their level of agreement with the statement: "The Corona regulations anger me," using a 7-point Likert-type scale from "Strongly disagree" to "Strongly agree" with a "Neutral" midpoint.

Information Behaviour

Respondents were asked how they accessed their primary news source for information about the pandemic with a multiple-choice question, including the response options: "Television," "News website," "Radio," "Social media," "Print newspaper" and "Mobile app."

Another multiple-choice item asked about the social media and messaging platforms used to access their selected primary news source, including "Facebook," "WhatsApp, Telegram, or Threema," "YouTube," "Instagram," and "Twitter." An additional option was provided: "I do not use social media."

For measuring the frequency with which respondents accessed information about the COVID-19 situation on the different social media and messaging platforms they had selected in the previous item, they were given a 7-point Likert-type scale ranging from "Never" to "Always," with "Sometimes" as the midpoint for each platform (using the same platform options referenced above).

Risk Assessment

Respondents were asked to indicate whether or not they considered themselves to be at high risk of developing serious health complications from COVID-19. They were also asked whether or not they considered someone else in their household to be at high risk. They were given a 7-point

Likert-type scale to register their response, from “Strongly disagree” to “Strongly agree” with a “Neutral” midpoint.

Respondents were also given the same response options to indicate their level of agreement with the statement: “I am concerned about my own health.”