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DISCUSSION PAPER SERIES

IZA DP No. 15897

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ABSTRACT

Who Gets Vaccinated? Cognitive and Non-cognitive Predictors of Individual Behavior in Pandemics*

This study investigates the different cognitive and non-cognitive characteristics associated with individuals' willingness to get vaccinated against Covid-19 and their actual vaccination status. Our empirical analysis is based on data obtained from three survey waves of about 2,000 individuals living in the German state of North Rhine-Westphalia. We find that individuals with a high level of trait reactance display a significantly lower willingness to get vaccinated. They also tend to get inoculated later or never. Moreover, neuroticism, locus of control, and risk literacy appear to be associated with the willingness to get vaccinated, but these results are less pronounced and less robust. Our results indicate that vaccination campaigns and policies could be improved by specifically addressing those with a high level of trait reactance.

JEL Classification: D91, H0, I12, I18

Keywords: COVID-19, vaccination, psychological traits, risk literacy, health literacy

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1 Introduction

Starting at the end of 2019, the Covid-19 pandemic spread out to the entire world quickly and forced many governments to implement public health measures. To decelerate infection and hospitalization dynamics, authorities mandated, for example, the use of face masks and compliance with regulations to keep distance. As vaccinations became available in 2020, particular hope was placed on vaccination campaigns, since inoculation is shown to prevent infections with Covid-19 from turning into severe cases and may even prevent infections altogether (CDC, 2022). The effectiveness of public health measures, including vaccination campaigns, depends critically on popular acceptance of and adherence to these measures. However, in many countries, there has been reluctance or refusal to follow the health guidelines and even strong protests against some of these measures, especially against vaccination requirements.

The search for explanations for this reluctance and refusal has led to a large body of research since the outbreak of the pandemic. Behavioral economic research has identified important cultural and group-level characteristics including a lack of trust (Bargain and Aminjonov, 2020), political polarization (Allcott et al., 2020), and cultural individualism (Bazzi et al., 2021; Chen et al., 2021) as important determinants of reluctance to follow health guidelines. On the individual level, Alfaro et al. (2022) and Fang et al. (2022) identified prosociality and social preferences as factors fostering compliance.

With this paper, we complement these lines of research by focusing on the role of cognitive and non-cognitive characteristics. Cognitive characteristics such as health and risk literacy can be expected to be relevant to vaccination decisions because they may contribute to an individual's ability to categorize the disparate statistical and health science information released during the pandemic and to make an informed decision based on that information. In addition, non-cognitive characteristics, such as personality traits, may play an important role in vaccination decisions, for example, by moderating recipients' reactions to persuasive messages (Hirsh et al., 2012), by shaping an individual's proneness to experience certain emotions (Widiger and Oltmanns, 2017), or by determining an individual's tendency to behave prosocially (Andor et al., 2022).

Specifically, we examine the association of trait reactance, neuroticism, locus of control beliefs, as well as health and risk literacy with individuals' vaccination status and willingness to get vaccinated against Covid-19.[1] Our analysis is based on three waves of survey data of more than 2,000 individuals living in the German state of North Rhine-Westphalia collected between May and November 2021. As our main outcome, we observe the self-reported vaccination status and, if the person is not yet vaccinated, the stated willingness to get vaccinated. For brevity, we refer to our main categorical outcome variable hereafter as

[1] Before obtaining our research data, we pre-registered our hypothesis that these characteristics may be associated with individual compliance with protective measures against Covid-19 (see Andor, 2021).

the willingness to get vaccinated, which includes the revealed preference of already being vaccinated as one category.

Our results indicate that the willingness to get vaccinated against Covid-19 decreases significantly with an increasing level of trait reactance, a personality characteristic that entails the personal tendency to perceive persuasion attempts as restricting one's freedom. Neuroticism, locus of control, and risk literacy also appear to be associated with the willingness to get vaccinated, but these results are less pronounced and less robust with regard to the econometric specification than the results regarding reactance. Health literacy is not significantly associated with the willingness to get vaccinated. The estimation of an Accelerated Failure Time model further shows that individuals with a high level of trait reactance get vaccinated significantly later than those with a low or medium level of trait reactance, while the remaining characteristics do not seem to be associated with the timing of the vaccination.

The results regarding reactance contribute to prior research in medicine and psychology, which has shown that trait reactance is negatively associated with individual efforts to follow official health recommendations (Díaz and Cova, 2022) as well as with vaccination intentions (Drażkowski and Trepanowski, 2022). We complement these findings by showing that trait reactance is strongly associated with actual vaccination behavior and that this association is of high economic significance, as the likelihood of being vaccinated against Covid-19 is 9 percentage points lower in the group of respondents with high trait reactance. Our results further suggest that higher levels of neuroticism, which have been shown to be related to self-protective behavior or adherence to public protection policies (e.g. Kroencke et al., 2020), do not seem to play a major role with regard to vaccination behavior. The same holds with regard to the roles of locus of control (see Devereux et al., 2021 and Olagoke et al., 2021) and health literacy (see Riiser et al., 2020 and Greer et al., 2021). Overall, our results underpin the importance of considering reactance when designing health policies and health communication campaigns (Reynolds-Tylus, 2019). Specifically, we conclude that campaigns and policies intended to encourage the unvaccinated to get inoculated should be specifically targeted at those with a high level of trait reactance.

The paper proceeds as follows. In the next section, we provide a detailed description of our data set. In Section 3, we present empirical evidence on the relationship between cognitive and non-cognitive traits and individuals' vaccination status and willingness to get vaccinated. Section 4 presents the results of an Accelerated Failure Time model to analyze the duration until first vaccination. Section 5 concludes.

2 Data

Our empirical analysis is based on data obtained from three survey waves of about 2,000 individuals living in the German state of North Rhine-Westphalia conducted by the RWI – Leibniz Institute for Economic Research in cooperation with the survey institute *forsa* throughout the year 2021. The first survey took place between May 7th and May 28th (Wave 1), followed by two additional waves collected between July 26th and August 17th (Wave 2) and October 20th and November 11th (Wave 3), respectively. For Wave 2 and Wave 3, we re-sampled as many participants from Wave 1 as possible to establish a panel data structure. The survey population consisted of a sub-sample of *forsa*'s household panel. *forsa* maintains a large panel of potential survey participants that is representative for the population of German-speaking internet users aged 14 and above. The data collection occurred as part of a research project that aimed at evaluating the epidemiological, economic, and social effects of a controlled redemption of the severe lockdown measures imposed to fight the Covid-19 pandemic in certain municipalities of North Rhine-Westphalia.[2] These so-called "Model Municipalities" have been over-sampled during the collection of the data, i.e., half of the survey participants live in these municipalities. The surveys were conducted online using a tool that can be accessed on computers, tablets, and smart-phones.

Approximately 3,000 respondents participated per survey wave. For our estimation sample, we consider only those individuals who participated in all three waves, which are 2,317 participants. Additionally, we exclude 100 participants who did not answer all questions relevant for our analysis, i.e., questions on their willingness to get vaccinated (elicited in all three survey waves) and their month of vaccination if they have already received their first vaccination dose (elicited in Wave 2), questions on cognitive and non-cognitive characteristics, as well as on age, gender, and education level (elicited in Wave 1). To obtain information on individuals' willingness to get vaccinated, we asked in May 2021: *"Vaccinations against Corona started in Germany at the end of December. Have you already been vaccinated against Corona, will you get vaccinated as soon as you have the chance, or would you rather wait or not get vaccinated at all?"*, allowing the following answers:

- *"I have already been vaccinated against Corona"* (Vaccinated)
- *"Will get vaccinated as soon as I have the chance"* (Willing)
- *"Will rather wait"* (Waiting)

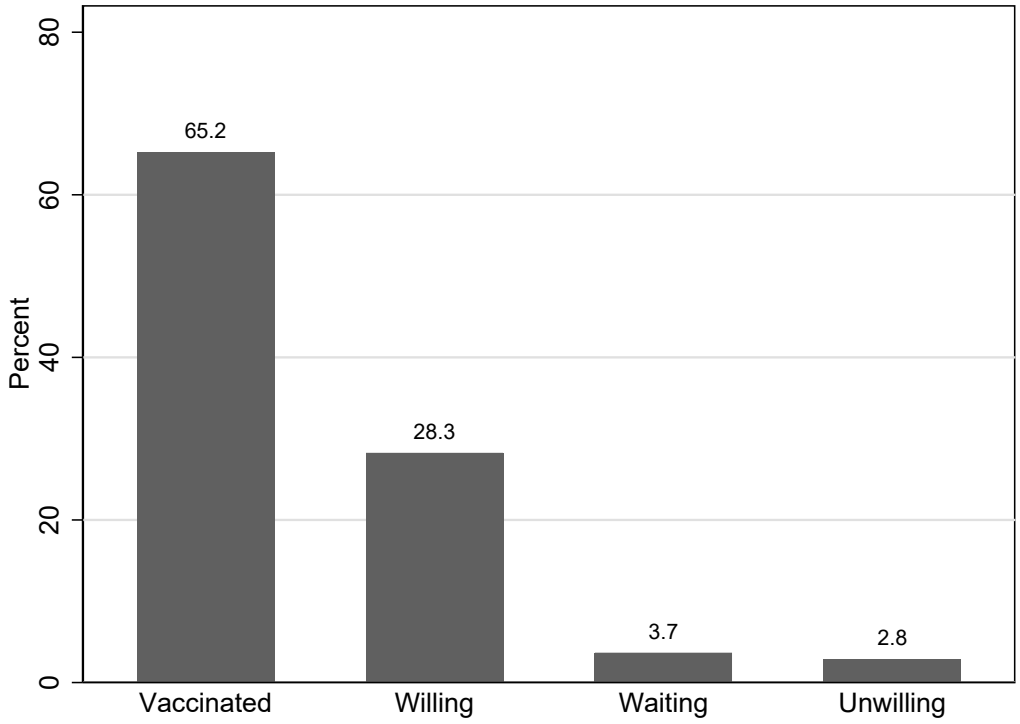
[2]These municipalities included the cities of Essen, Hamm, Cologne, Krefeld, Mönchengladbach, Lennestadt, Lippstadt, Münster, and Soest, as well as the counties of Coesfeld, Düren, Paderborn, and Warendorf.

- *"Will not be vaccinated at all"* (Unwilling)
- *"Do not know / do not specify"*

We count the 13 respondents who reported to not know or who preferred not to specify their vaccination status as part of the 100 excluded participants who did not answer all questions relevant to our analysis. In addition, we delete 37 respondents from the sample as they provided inconsistent responses with regard to their vaccination dates.[3] The final estimation sample consists of 2,180 individuals.

Figure 1 shows the distribution of the willingness to get vaccinated in May 2021 as it appears in our final sample. A majority of 65% of the respondents was already vaccinated in May 2021, and most of the respondents who were not yet vaccinated were at least willing to get vaccinated (28%). Only a minority of about 4% and 3% of the individuals in our sample preferred to wait or reported to not get vaccinated at all, respectively.

Figure 1: Vaccination status and willingness to get vaccinated in May 2021



Number of observations: 2,180.

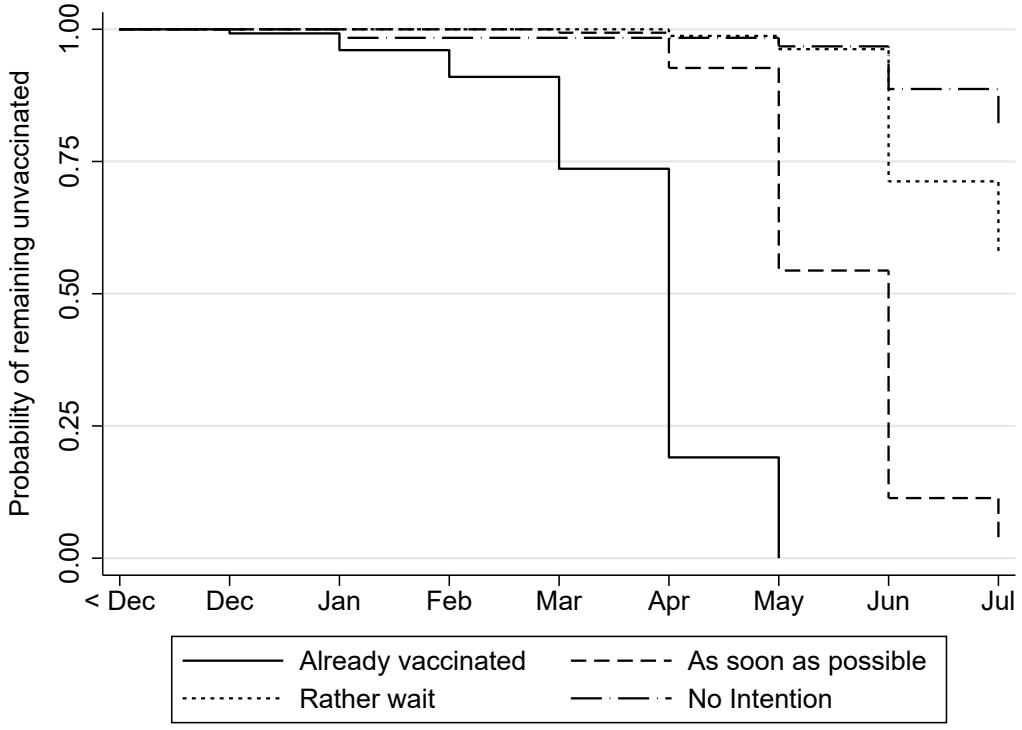
In Wave 2, conducted in July and August 2021, we asked the respondents who were already vaccinated at this point in time (94.6%) about the month in which they received their first vaccination dose. These vaccination dates were influenced by a priority scheme

[3]These respondents stated in May that they had already been vaccinated, but indicated in the second survey wave that they had been vaccinated in June or July.

imposed by the German government to ensure that the most vulnerable groups for infections were vaccinated first. From the start of the vaccination campaign in December 2020 until April 6, 2021, persons aged 80 or older as well as persons who work in nursing, elder care, and health care were prioritized. From April 6, 2021, to May 6, 2021, the prioritization was extended to persons aged 70 or older as well as to chronically ill persons and their close relatives or caregivers, contact persons of pregnant persons, as well as persons in public service, such as the police, fire department, and school service. From May 6, 2021, to June 7, 2021, the prioritization was further extended to persons aged 60 or older and to further professional groups that have a lot of contact with customers or work in system-relevant utilities. From 7 June, 2021, there was no longer any special prioritization and everyone could be vaccinated.

Figure 2 contrasts the vaccination intentions elicited in Wave 1 with the vaccination timing elicited in Wave 2. It appears that the large majority of those who stated in May that they will get vaccinated as soon as possible, indeed got vaccinated in May, June or July. Only a small share of this group was still not vaccinated at the time of Wave 2 (3.4%). In contrast, 57.5% of those who stated that they would rather wait before getting vaccinated in Wave 1 and 82.3% of those who stated no intention to get vaccinated at all were still not vaccinated in Wave 2.

Figure 2: Kaplan-Meier plot of vaccination months as stated in July/August 2021 differentiated by the vaccination intentions stated in May 2021



Number of observations: 2,180.

Table 1 presents summary statistics of the outcome and explanatory variables used in our empirical analysis. The latter can be categorized into two groups: Variables describing the cognitive and non-cognitive characteristics of the individuals in our sample, which are in the focus of this study, and socio-economic characteristics. We measured five different cognitive and non-cognitive characteristics that we considered relevant to vaccination decisions based on the scientific literature[4] as well as theoretical considerations: trait reactance, neuroticism, and locus of control, as well as risk and health literacy.

Trait reactance is proxied using three selected items from the Hong Psychological Reactance Scale (Hong and Faedda, 1996). The personality construct that this scale is supposed to measure is psychological reactance, defined as "the motivational state that is hypothesized to occur when a freedom is eliminated or threatened with elimination" (Brehm and Brehm, 1981, p. 37) and "reactance produces a desire to restore one's attitudinal or behavioral freedom" (Shen and Dillard, 2005, p. 74). While reactance can be viewed as a motivational state, it is argued that it can also be viewed as a personality trait that determines a person's proneness to feel and act in a reactant manner (Shen and Dillard, 2005).

Neuroticism was retrieved using the neuroticism-related items of the Big Five Inventory (BFI-S) that is used in the German Socio-Economic Panel (see Schupp and Gerlitz, 2008). This personality trait has two poles: neuroticism on one side and emotional stability on the other. Persons who score high on neuroticism have a stronger tendency to experience negative emotions such as anxiety, anger, guilt, and depression (Widiger, 2009, p. 129).

Locus of control was captured using the original items from the Psychological Coping Resources component of the Mastery Module by Pearlin and Schooler (1978), which is, for example, also used to measure locus of control in Cobb-Clark and Schurer (2013). Locus of control captures an individual's belief about how strongly events in her life are shaped by own behavior (Gatz and Karel, 1993; Rotter, 1966). Individuals who believe that events strongly depend on own behavior have a high internal locus of control, while those believing that events are mainly determined by fate or luck, for instance, have an external locus of control.

Health literacy was measured using three selected items from the extended numeracy scale by Lipkus et al. (2001).[5] Finally, we constructed an indicator of risk literacy using the short version of the Berlin Numeracy test, proposed by Cokely et al. (2012).[6] These

[4]On trait reactance, see Díaz and Cova (2022) and Ball and Wozniak (2022). On neuroticism, see Kroencke et al. (2020). On locus of control, see Devereux et al. (2021) and Olagoke et al. (2021). On risk and health literacy, see Riiser et al. (2020) and Greer et al. (2021).

[5]These items are primarily concerned with numerical calculations. Based on their results, Lipkus et al. (2001) state that "there was no evidence to suggest that performing mathematical operations in the context of health risks differs from other simple mathematical processes in other contexts" (Lipkus et al., 2001, p. 41).

[6]The Berlin Numeracy test measures statistical numeracy and risk literacy and "was found to be the strongest predictor of comprehension of everyday risks (e.g., evaluating claims about products and

Table 1: Summary statistics based on the first survey wave (May 2021)

Variable	Explanation	Mean	Std. Dev.
(I) Outcome variables			
Vaccinated	Dummy: 1 if respondent is already vaccinated	0.65	–
Willing	Dummy: 1 if respondent is willing to get vaccinated as soon as possible	0.28	–
Waiting	Dummy: 1 if respondent prefers to wait	0.04	–
Unwilling	Dummy: 1 if respondent is unwilling to get vaccinated	0.03	–
(II) Cognitive and non-cognitive characteristics			
Reactance			
Low	Dummy: 1 if respondent has a low level of reactance	0.24	–
Medium	Dummy: 1 if respondent has a medium level of reactance	0.32	–
High	Dummy: 1 if respondent has a high level of reactance	0.44	–
Neuroticism			
Low	Dummy: 1 if respondent has a low level of neuroticism	0.33	–
Medium	Dummy: 1 if respondent has a medium level of neuroticism	0.29	–
High	Dummy: 1 if respondent has a high level of neuroticism	0.38	–
Locus of Control			
Low	Dummy: 1 if respondent has a low locus of control	0.30	–
Medium	Dummy: 1 if respondent has a medium locus of control	0.31	–
High	Dummy: 1 if respondent has a high locus of control	0.39	–
Health Literacy			
Low	Dummy: 1 if respondent has a low risk literacy	0.30	–
High	Dummy: 1 if respondent has a high health literacy	0.70	–
Risk literacy	Dummy: 1 if respondent passed the Berlin Numeracy Test (short version)	0.25	–
(III) Socio-economic characteristics			
Female	Dummy: 1 if respondent is a woman	0.47	–
Age	Age of respondent	57.8	14.4
College degree	Dummy: 1 if respondent has a college degree	0.34	–

Number of observations: 2,180.

measures elicit facets of numeracy that may be important for assessing risks regarding Covid-19 infections and vaccine side effects.

For our empirical analysis, we first calculate the individual mean responses on the Likert scales for all items of each characteristic. Second, we divide the sample for each characteristic into three approximately equally sized categories: Low (the mean of the responses is below the lower tercile), medium (the mean of the responses is between the lower and the upper tercile), high (the mean of the responses is above the upper tercile).[7] Exceptions are the measures of health and risk literacy. The health literacy measure yields only one binary response (correct or incorrect) per item. To aggregate the items, we

treatments; interpreting forecasts) [...]" (Cokely et al., 2012, p. 25) compared to alternative measures of numeracy or cognitive abilities.

[7]Since the mean responses tend to consist of a limited number of discrete values due to the small number of items per trait, there is a high probability for ties in which one of these discrete values lies exactly on the tercile boundary. In this case, we assign all respondents with this value to the higher group. For this reason, the respective groups are not exactly of the same size. In Appendix C, we conduct robustness checks and form the groups in an alternative way: The low category consists of those individuals whose rounded mean response on the Likert scale of all items of a characteristic is either 1 or 2. The medium category consists of those whose mean response is 3 (on 5-point Likert scales) or 3, 4 or 5 (on 7-point Likert scales). The high category consists of the remainder. This approach results in more unequally sized groups, where the low and high categories tend to consist of those with a rather extreme realization of the respective characteristic.

calculate the sum of the correct answers per respondent, which reveals that almost 70% of the respondents answered all items correctly. Since this 70% includes both the lower and the upper tercile, there are only two categories for this measure: Low health literacy (at least one incorrect response) and high health literacy (all responses are correct). Similarly, our measure of risk literacy, the short form of the Berlin Numeracy test, produces only one binary result (correct or incorrect). Therefore, we use a dummy variable that is 1 if the correct answer to the test was given, which is true for 25% of the individuals in our sample, and 0 if the answer was wrong or the answer option "don't know" was chosen.

The socio-economic characteristics of our sample closely resemble the German averages regarding the gender ratio (47% females compared to 50.5%; Destatis, 2022) and the share of persons with a college degree (34% compared to 33.4%; Destatis, 2022). In contrast, the average age (55.3 years compared to 44.5; BiB, 2022) and consequently the share of vaccinated individuals (65% in May 2021 compared to 43% on June 1st, 2021; RKI, 2021) are higher than in the population.

3 Willingness to get vaccinated

To investigate the relationship between cognitive and non-cognitive traits and individuals' willingness to get vaccinated, we estimate regression models of the following form:

$$Prob(Y_i = j) = F(X, \beta), \tag{1}$$

where the dependent variable Y_i describes the categorical measure of individual i's willingness to get vaccinated ($j = 0, ..., J$) and the vector X_i encompasses the different indicators of cognitive and non-cognitive traits of individual i described in the last section as well as potential confounding factors, including gender, age, and level of education. Because of the discrete nature of our dependent variable, Equation (1) has been estimated using a Multinomial Logit mode, i.e., $F(X, \beta) = e^{\beta_j' X_i} / \sum_{j=0}^{J} e^{\beta_j' X_i}$, where the β's are the main coefficients of interest.

Table 2 reports the estimated average marginal effects with the willingness to get vaccinated elicited in Wave 1 (May 2021) as the outcome variable. We conduct the analyses in two forms. In the first four columns of Table 2, every Panel refers to a separate regression, e.g., Panel A shows the marginal effects obtained from a regression considering only trait reactance and the socio-economic characteristics as explanatory variables, while ignoring the other characteristics. In the second four columns, all panels result from the same regression model, i.e., the regression model includes all cognitive and non-cognitive traits together with the socio-economic characteristics as explanatory variables.

First, we focus on the separate models depicted in the first four columns of Table 2.

Panel A of Table 2 suggests that the willingness to get vaccinated is lower for persons with a high level of trait reactance. Compared to individuals with a low level of reactance, individuals with a high level of reactance are significantly less likely to be vaccinated (by 9.1 percentage points) and significantly more likely to prefer to wait until they get vaccinated (by 4.7 percentage points) or to be unwilling to get vaccinated at all (by 5.6 percentage points). The evidence appears to be somewhat less clear when we consider neuroticism (Panel B of Table 2). While individuals with a high level of neuroticism display a significantly lower probability of being unwilling to get vaccinated (by 1.9 percentage points), all other coefficients appear to be statistically insignificant at conventional levels. Moreover, we find that individuals with a high level of internal locus of control are significantly more likely to get vaccinated (by 5.3 percentage points) than those with a low level of internal locus of control (Panel C of Table 2). The measure of health literacy does not appear to be related with the willingness to get vaccinated (Panel D of Table 2). Regarding risk literacy, we find that respondents who passed the Berlin test are significantly more willing to get vaccinated (by 5.1 percentage points).

Table 2: Marginal effects of Multinomial Logit models on the willingness to get vaccinated in May 2021

	Willingness to get vaccinated							
	Separate models				**Combined model**			
	Willing		**Hesistant**		**Willing**		**Hesistant**	
	Vaccinated	Willing	Waiting	Unwilling	Vaccinated	Willing	Waiting	Unwilling
Panel A: Reactance								
Medium	-0.008	-0.002	0.009	0.002	-0.007	-0.003	0.008	0.002
	(0.025)	(0.024)	(0.007)	(0.003)	(0.025)	(0.024)	(0.008)	(0.003)
High	-0.091**	-0.011	0.047**	0.056**	-0.086**	-0.014	0.045**	0.055**
	(0.024)	(0.023)	(0.009)	(0.008)	(0.024)	(0.023)	(0.009)	(0.008)
Panel B: Neuroticism								
Medium	0.017	-0.017	0.009	-0.010	0.029	-0.016	0.004	-0.017
	(0.024)	(0.023)	(0.011)	(0.010)	(0.024)	(0.023)	(0.011)	(0.011)
High	0.002	0.015	0.002	-0.019*	0.021	0.012	-0.004	-0.029**
	(0.022)	(0.022)	(0.009)	(0.009)	(0.024)	(0.024)	(0.010)	(0.010)
Panel C: Locus of Control								
Medium	0.040	-0.025	-0.001	-0.014	0.035	-0.020	0.001	-0.015
	(0.024)	(0.023)	(0.011)	(0.009)	(0.024)	(0.024)	(0.010)	(0.009)
High	0.053*	-0.023	-0.016	-0.014	0.044	-0.019	-0.010	-0.015
	(0.022)	(0.022)	(0.010)	(0.009)	(0.024)	(0.024)	(0.010)	(0.009)
Panel D: Health Literacy								
Low	0.020	-0.018	-0.002	-0.001	0.014	-0.012	-0.002	0.000
	(0.021)	(0.021)	(0.009)	(0.008)	(0.021)	(0.021)	(0.009)	(0.008)
Panel E: Risk Literacy								
Test passed	-0.033	0.051*	-0.008	-0.010	-0.033	0.052*	-0.009	-0.011
	(0.023)	(0.021)	(0.010)	(0.009)	(0.024)	(0.023)	(0.009)	(0.008)
Number of observations	1,422	616	80	62	1,422	616	80	62

Note: Robust standard errors are reported in parentheses. All regressions include socio-economic characteristics as control variables. ** and * indicate statistical significance at the 1% and 5% level, respectively.

When focusing on the combined model shown in the last four columns of Table 2, we find that most results are similar to the separate models. Yet, the effect of locus of

control on vaccination is less pronounced and not statistically significant in the combined model. Instead, the relation between a high level of neuroticism and unwillingness to get vaccinated becomes slightly larger. One potential explanation is that locus of control and neuroticism are to some extent collinear, as suggested by Judge et al. (2002), who argue that neuroticism and locus of control may be indicators of a common core construct. Indeed, in our data, we find a relatively high and significant negative correlation between the two constructs ($r = -0.36,$ p-value < 0.000).

In all our analyses we control for gender, age, and education level of the participants. The effects of these variables on the willingness to get vaccinated appear to be robust across all specifications of our model. As an example, Table A1 in the Appendix shows the estimated coefficients of these covariates when regressing vaccination status on these covariates only. Age is significantly positively correlated with being vaccinated. One additional year is associated with an increase in the vaccination probability by 1.3 percentage points. Given the priority schemes for the distribution of vaccine doses by the German government described in the last section and due to the higher risk for a severe course of the disease among elderly persons, this effect is not surprising. The results related to respondents' gender are not entirely conclusive, as we find that women are less likely to be willing to be vaccinated (4.1 percentage points), but in turn have a slightly but not significantly higher probability of already being vaccinated (3.2 percentage points). In contrast, there are no gender differences in the probabilities of preferring to wait or not wanting to be vaccinated. Lastly, we find that participants with a university degree are significantly more likely to be vaccinated by 8.8 percentage points and significantly less likely to prefer to wait (2.9 percentage points) or being unwilling to get vaccinated (by 2.7 percentage points) compared to those without a university degree.

The results regarding the association between reactance and vaccination status appear to be robust to several robustness checks. First, we repeat the regressions shown in Table 2 for the different waves of our survey. When performing the same estimations for the waves conducted in July/August and October/November, respectively, the results are very similar to those for the wave conducted in May (Tables A4, A5). This is also true when we estimate the same regression for the total cross-sectional sample of the wave conducted in May rather than using the sample of those who participated in all three waves (see Table A6) as well as when conducting a regression for the pooled sample of all three waves (Table A7). Second, we estimated a Probit model for our main estimation sample, where the binary outcome variable equals one if a person has already received a vaccination dose and zero otherwise (Table A8). While we find a strong and statistically significant relationship between the vaccination status and the level of reactance throughout all robustness checks, the relations with the other characteristics seem much weaker and less robust. For example, the associations between the willingness to get vaccinated and locus of control as well as

risk literacy vanish when considering the vaccination status measured in the third survey wave conducted in fall 2021 (see e.g. Table A5).

4 Timing of vaccinations

In the survey wave conducted in July and August 2021 (Wave 2), we asked the respondents who were already vaccinated at this point in time (94.6%) about the month in which they received their first vaccination dose. This information allows us to analyze the effects of cognitive and non-cognitive traits on actual vaccination behavior using an Accelerated Failure Time (AFT) model. The AFT model estimates the hazard function $\lambda(\cdot)$ in the following form:

$$\lambda_i(t, X_i, \beta) = \lambda_0(t) exp(X_i'\beta), \tag{2}$$

where X_i contains the same factors as in Section 3 and $\lambda_0(t)$ determines the baseline hazard. Individuals who did not get vaccinated by August 2021 are treated as being right-censored.

The AFT model requires distributional assumptions about the baseline hazard, but does not rely on the assumption of proportional hazards.[8] To decide which distribution function to assume, we fitted a model including covariates to four common distributions: Exponential, Log-Logistic, Log-Normal, and Weibull. According to the resulting Akaike and Bayesian information criterion, the Weibull distribution appears to provide the best fit, and the Log-Logistic distribution the second best fit (see Table 3). For our main analyses, we thus decide to rely on the Weibull model. The results of the Log-Logistic model, which differ only slightly from the results of the Weibull model, are reported in Table A9 in the Appendix.

Table 3: Evaluation of the AFT model-fit assuming different distributions

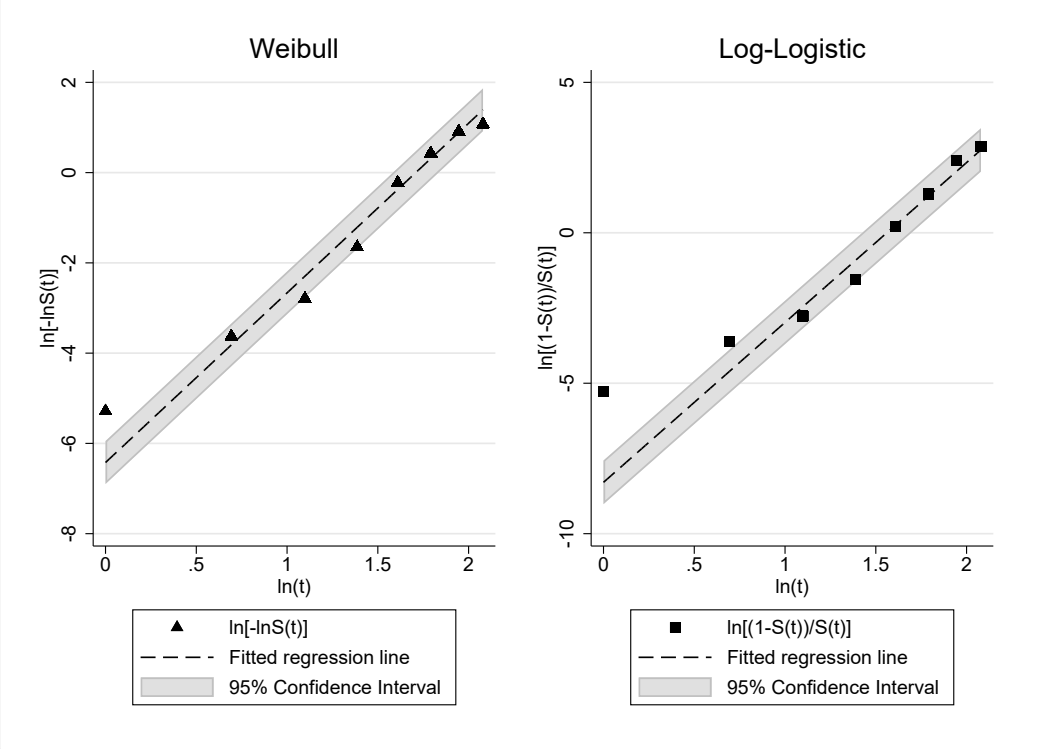
Distribution	AIC	BIC
Exponential	4,590	4,670
Log-Logistic	535	620
Log-Normal	1,015	1,100
Weibull	463	549

Note: The AFT models underlying this evaluation include reactance, locus of control, neuroticism, risk and health literacy, education, gender, and the age group as covariates.

[8]The natural alternative to estimating an AFT model is a Proportional Hazards model (Cox, 1972). However, for our data the conventional tests of the underlying assumption of proportional hazards indicate that this assumption does not hold with respect to the different age priority groups described in Section 2. Even though one might be able to allow for this heterogeneity by estimating a stratified model that allows the baseline hazard to differ across age groups (see e.g. Kleinbaum and Klein, 2012b), the crucial assumption of this stratified model, i.e., that the remaining covariates do not interact with the variables stratified on, does not hold either.

Following Allison (2010) and Kleinbaum and Klein (2012a), Figure 3 provides graphical tests of the appropriateness of these two distributional assumptions. These tests rely on the specific properties of the different models. Under the assumption of a Weibull distribution, the log of the survival time $ln(t)$ should theoretically be in line with $ln[-ln\hat{S}(t)]$, where $\hat{S}(t)$ presents the Kaplan-Meier estimate of the survival function. Similarly, under the Log-Logistic distribution, the log of the survival time $ln(t)$ should be in line with $ln[\frac{1-\hat{S}(t)}{\hat{S}(t)}]$. These relationships are plotted in Figure 3, where the dashed line represents a fitted linear regression line along with its 95% confidence interval. Ideally, all values of $ln[-ln\hat{S}(t)]$ or $ln[\frac{1-\hat{S}(t)}{\hat{S}(t)}]$, respectively, would fall within the confidence interval of the regression line (Allison, 2010). Figure 3 indicates that both models fit the data well, with the Weibull model fitting somewhat better than the Log-Logistic model, as expected based on the information criteria.

Figure 3: Graphical inspection of the distributional assumptions in the AFT model



Given the Weibull distribution and time-constant covariates, we can simplify the model in Equation (2) to a model in which the logarithm of the time until vaccination $ln(T_i)$ is a linear function of the covariates (Allison, 2010; Kroszner and Strahan, 1999):

$$ln(T_i) = X_i'\beta^* + \frac{1}{p}\varepsilon_i, \tag{3}$$

where ε_i has an extreme value distribution and p is the shape parameter of the Weibull distribution. The parameter vector β^* is directly related to the parameter vector β in Equation (2) as $\beta^* = -\frac{1}{p}\beta$ (Kroszner and Strahan, 1999).

Table 4: Coefficients of Accelerated Failure Time models (Weibull distribution) on the time until vaccination

	(1)	(2)	(3)	(4)	(5)	(6)
Medium Reactance	0.019	–	–	–	–	0.019
	(0.013)	–	–	–	–	(0.012)
High Reactance	0.088**	–	–	–	–	0.087**
	(0.012)	–	–	–	–	(0.012)
Medium Neuroticism	–	0.010	–	–	–	0.002
	–	(0.013)	–	–	–	(0.013)
High Neuroticism	–	-0.008	–	–	–	-0.015
	–	(0.012)	–	–	–	(0.012)
Medium Locus of Control	–	–	0.004	–	–	0.010
	–	–	(0.013)	–	–	(0.013)
High Locus of Control	–	–	-0.016	–	–	-0.005
	–	–	(0.012)	–	–	(0.012)
High Health Literacy	–	–	–	0.001	–	-0.002
	–	–	–	(0.012)	–	(0.012)
Risk Literacy test passed	–	–	–	–	0.010	0.012
	–	–	–	–	(0.014)	(0.013)
University degree	-0.044**	-0.047**	-0.044**	-0.046**	-0.048**	-0.047**
	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)
Female	-0.002	-0.003	-0.005	-0.004	-0.003	-0.000
	(0.010)	(0.011)	(0.010)	(0.011)	(0.011)	(0.011)
$80 >$ Age ≥ 70	0.116**	0.114**	0.109**	0.112**	0.113**	0.117**
	(0.031)	(0.033)	(0.034)	(0.033)	(0.033)	(0.030)
$70 >$ Age ≥ 60	0.196**	0.198**	0.197**	0.197**	0.198**	0.196**
	(0.032)	(0.034)	(0.035)	(0.034)	(0.034)	(0.031)
Age ≤ 60	0.306**	0.316**	0.310**	0.313**	0.312**	0.306**
	(0.031)	(0.032)	(0.033)	(0.033)	(0.033)	(0.030)
Constant	1.538**	1.580**	1.589**	1.582**	1.581**	1.541**
	(0.030)	(0.032)	(0.032)	(0.032)	(0.031)	(0.030)
$ln(p)$	1.568**	1.551**	1.551**	1.550**	1.550**	1.570**
	(0.021)	(0.022)	(0.022)	(0.022)	(0.022)	(0.021)

Note: Robust standard errors are reported in parentheses. ** and * indicate statistical significance at the 1% and 5% level, respectively. Number of observations: 2,180.

The estimation results from the Weibull model in terms of β^* are presented in Table 4. Columns (1) to (5) present regressions in which the different cognitive and non-cognitive characteristics enter separately, while they enter simultaneously in the regression presented in Column (6). Consistent with the empirical results reported in the last section, high reactance seems to be strongly related with a later vaccination date (Columns (1) and (6)). As the AFT model is estimated in log-linear form, we take the exponential of the parameters to provide a quantitative interpretation. Thus, based on Column (6), the exponential of the coefficient on high reactance is $exp(0.088) = 1.09$. Hence, compared to individuals with a low level of reactance, the time until vaccination is typically 9% higher for persons with a high level of reactance. In contrast, the remaining cognitive and non-cognitive characteristics are not significantly related with vaccination timing.

The coefficients on the covariates suggest that the time until vaccination is around 4% shorter for respondents with a university degree. No significant association is found with regards to the respondents' gender. The dummy variables indicating the age priority groups reveal that older persons exhibit a shorter time until vaccination, as expected due to the prioritization scheme described in Section 2.

The results assuming a Log-Logistic distribution corroborate the main results from the Weibull model (see Table A9 in the Appendix). The exception is that in this model, a high internal locus of control seems to be significantly related with a shorter time until vaccination. Yet, this effect disappears in the combined model (Column (6) of Table A9). This suggests that the results concerning locus of control are less robust than those concerning reactance.

An additional robustness check is presented in Table A10 in the Appendix. This robustness check examines the extent of possible time aggregation bias, which arises because the observed vaccination dates are discrete in nature due to the monthly observation rhythm, even though the model assumes continuous data (Petersen, 1991). To assess the sensitivity of our results in this regard, we follow Allison (2010) and recode our data to be interval censored, i.e., rather than assigning respondents a specific month-indicator as the outcome variable, we assign them an interval where the upper interval bound is the month-indicator used before and the lower interval bound is the previous month-indicator plus an epsilon of 0.0001. The latter has the purpose of avoiding zeros for respondents who were vaccinated in the first month observed. Respondents who were not vaccinated at the end of the observation period are assigned an interval that has an open upper interval bound, while the lower interval bound takes the value of the latest observed month. This interval censored data can also be analyzed by a Weibull AFT model. The results obtained by using this interval censored model are qualitatively similar to the ones in Table 4 (see Table A10 in the Appendix). In tendency, the coefficients of the interval censored model are somewhat larger, but there are no changes in the signs or significance of the results.

As a final robustness check, we examine the extent to which the results are driven by individuals who were not yet vaccinated at the time the vaccination dates were elicited and who therefore enter the AFT model as right-censored observations. To do this, we omit these individuals from the estimation sample (Table A11 in the Appendix). The signs and significance of the resulting coefficients are similar to the results in Table 4. A high level of trait reactance is still significantly associated with a later vaccination date, although the magnitude of this relationship is smaller than in the model that includes unvaccinated individuals.

5 Conclusion

Using data obtained from three survey waves of about 2,000 individuals living in the German state of North Rhine-Westphalia, this paper investigates the association of different cognitive and non-cognitive characteristics with an individuals' willingness to get vaccinated against Covid-19 as well as their vaccination status. The empirical results indicate that trait reactance is the strongest predictor of vaccination behavior. The probability of being

vaccinated against Covid-19 is 9 percentage points lower for individuals with a high level of trait reactance, compared to those with a low or medium level of trait reactance. In addition, the time to vaccination is generally 9% higher such individuals. Furthermore, we find tentative evidence that higher risk literacy, a higher internal locus of control, and a more pronounced level of neuroticism are related to vaccination intentions. However, these results are less robust than those regarding reactance.

As our results represent correlations rather than causal effects, we cannot claim that a hypothetical change in the personality traits considered will bring about a direct change in the willingness to get vaccinated. However, changing personality traits is usually not a policy goal and especially not a goal for health campaigns designed to create a short-term impact on behavior. Rather, to assess the relevance of our results, it is important to assume that differences in personality traits are predictive of individual differences in responses to campaigns and policies. This is especially likely to apply to trait reactance, since this measure is explicitly intended to assess one's personal tendency to feel reactance when confronted with, for example, external persuasion attempts (Shen and Dillard, 2005).

With regard to policy implications, our results indicate that vaccination campaigns and policies could be improved by specifically addressing certain groups of people, in particular those with a high level of trait reactance. To create such targeted measures, we can build on literature predating the Covid-19 pandemic, which discusses ways to overcome reactance in health communication (see, for instance, the literature review by Reynolds-Tylus, 2019). For example, future vaccination campaigns could use narratives that promote empathy, as Shen (2010) has shown that state empathy can attenuate reactance regarding persuasive messages related to smoking and alcohol use. Moreover, persuasive messages may differ in the extent to which they are perceived as freedom threatening. According to the results of a meta-analysis by Rains (2013), the use of less freedom-threatening language may reduce reactant reactions to such messages.

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A Appendix: Survey modules to elicit cognitive and non-cognitive characteristics

A.1 Risk literacy

Risk literacy is measured as the single-item format of the Berlin numeracy test proposed by (Cokely et al., 2012):

> Out of 1,000 people in a small town 500 are members of a choir. Out of these 500 members in a choir 100 are men. Out of the 500 inhabitants that are not in a choir 300 are men. What is the probability that a randomly drawn man is a member of the choir?
>
> Please indicate the probability as a percent: _____%

A.2 Health literacy

Health literacy is measured using three selected items from the numeracy scale by Lipkus et al. (2001):

- Which of the following numbers represents the biggest risk of getting a disease?

  a) 1 in 100

  b) 1 in 1000

  c) 1 in 10

- If the chance of getting a disease is 10%, how many people would be expected to get the disease?

  _____ in 1000

- If the chance of getting a disease is 20 out of 100, this would be the same as having a

  _____% chance of getting the disease.

A.3 Locus of Control

Locus of Control is elicited using the items of the Psychological Coping Resources component of the Mastery Module by Pearlin and Schooler (1978), as for example also used by Cobb-Clark and Schurer (2013):

> In the following we would like to ask you to indicate to what degree you agree with the following statements on a scale from 1 (disagree completely) to 7 (fully agree).

1. I have little control over the things that happen to me.
2. There is really no way I can solve some of the problems I have.
3. There is little I can do to change many of the important things in my life.
4. I often feel helpless in dealing with the problems of life.
5. Sometimes I feel that I'm being pushed around in life.
6. What happens to me in the future mostly depends on me.
7. I can do just about anything I really set my mind to do.

A.4 Neuroticism

Neuroticism is elicited using the appropriate items from the short inventory to measure the Big Five personality traits (BFI-S) that is used in the German Socio-Economic Panel (see Schupp and Gerlitz, 2008).

> In the following we would like to ask you to indicate to what degree you agree with the following statements on a scale from 1 (disagree completely) to 7 (fully agree).

1. I am someone who often worries.
2. I am someone who gets nervous easily.
3. I am someone who is relaxed and can handle stress well.

A.5 Reactance

The individual proneness to exhibit reactant behavior is measured using three selected items from the Hong Psychological Reactance Scale (Hong and Faedda, 1996).

> In the following we would like to ask you to indicate to what degree you agree with the following statements on a scale from 1 (disagree completely) to 5 (fully agree).

1. I become frustrated when I am unable to make free and independent decisions.
2. Regulations trigger a sense of resistance in me.
3. Advice and recommendations usually induce me to do just the opposite.

B Appendix: Covariates

Table A1: Marginal effects of a Multinomial Logit model on the willingness to get vaccinated in May 2021 — socio-economic characteristics

	Willingness to get vaccinated			
	Willing		**Hesitant**	
	Vaccinated	Willing	Waiting	Unwilling
Age	0.013**	-0.011**	-0.001**	-0.001**
	(0.001)	(0.001)	(0.000)	(0.000)
Female	0.032	-0.041*	0.005	0.004
	(0.019)	(0.018)	(0.008)	(0.007)
College degree	0.088**	-0.032	-0.029**	-0.027**
	(0.021)	(0.019)	(0.010)	(0.009)
Number of observations	1,422	616	80	62

Note: Robust standard errors are reported in parentheses.
** and * indicate statistical significance at the 1% and 5% level, respectively.

C Appendix: Alternative categories of cognitive and non-cognitive characteristics

Table A2: Summary statistics for cognitive and non-cognitive characteristics based on the first survey wave (May 2021) – alternative specification of groups

Variable	Explanation	Mean	Std. Dev.
Reactance			
Low	Dummy: 1 if respondent has a low level of reactance	0.56	0.50
Medium	Dummy: 1 if respondent has a medium level of reactance	0.33	0.47
High	Dummy: 1 if respondent has a high level of reactance	0.11	0.32
Neuroticism			
Low	Dummy: 1 if respondent has a low level of neuroticism	0.26	0.44
Medium	Dummy: 1 if respondent has a medium level of neuroticism	0.67	0.47
High	Dummy: 1 if respondent has a high level of neuroticism	0.06	0.24
Locus of Control			
Low	Dummy: 1 if respondent has a low locus of control	0.05	0.22
Medium	Dummy: 1 if respondent has a medium locus of control	0.50	0.50
High	Dummy: 1 if respondent has a high locus of control	0.45	0.50
Risk literacy	Dummy: 1 if respondent passed the Berlin Numeracy Test (short version)	0.25	0.43
Health Literacy			
Low	Dummy: 1 if respondent has a low risk literacy	0.10	0.30
Medium	Dummy: 1 if respondent has a medium risk literacy	0.20	0.40
High	Dummy: 1 if respondent has a high health literacy	0.70	0.46

Note: The low category consists of those individuals whose rounded mean response on the Likert scale of all items of a characteristic is either 1 or 2. The medium category consists of those whose mean response is 3 (on 5-point Likert scales) or 3, 4 or 5 (on 7-point Likert scales). The high category consists of the remainder. Number of observations: 2,180.

Table A3: Marginal effects of Multinomial Logit models on the willingness to get vaccinated in May 2021 – alternative specification of groups

	Willingness to get vaccinated							
	Separate models				**Combined model**			
	Willing		**Hesistant**		**Willing**		**Hesistant**	
	Vaccinated	Willing	Waiting	Unwilling	Vaccinated	Willing	Waiting	Unwilling
Panel A: Reactance								
Medium	-0.054**	0.005	0.026**	0.024**	-0.053*	0.002	0.025**	0.025**
	(0.020)	(0.020)	(0.008)	(0.006)	(0.021)	(0.020)	(0.008)	(0.006)
High	-0.179**	-0.047	0.086**	0.140**	-0.165**	-0.044	0.084**	0.125**
	(0.031)	(0.028)	(0.020)	(0.021)	(0.031)	(0.029)	(0.020)	(0.019)
Panel B: Neuroticism								
Medium	0.037	-0.023	0.012	-0.027*	0.051*	-0.026	0.009	-0.034**
	(0.022)	(0.021)	(0.009)	(0.011)	(0.023)	(0.022)	(0.009)	(0.011)
High	-0.014	0.020	0.022	-0.028	0.020	0.000	0.018	-0.038*
	(0.043)	(0.043)	(0.018)	(0.015)	(0.044)	(0.044)	(0.017)	(0.015)
Panel C: Locus of Control								
Medium	0.143**	-0.085	-0.015	-0.043	0.119*	-0.090	-0.002	-0.027
	(0.047)	(0.045)	(0.022)	(0.024)	(0.048)	(0.046)	(0.017)	(0.017)
High	0.161**	-0.083	-0.030	-0.048*	0.137**	-0.096*	-0.009	-0.032
	(0.047)	(0.045)	(0.022)	(0.023)	(0.049)	(0.048)	(0.017)	(0.017)
Panel D: Health Literacy								
Low	0.018	-0.036	0.002	0.016	0.023	-0.027	-0.004	0.009
	(0.033)	(0.032)	(0.014)	(0.015)	(0.032)	(0.032)	(0.013)	(0.011)
Medium	0.022	-0.009	-0.004	-0.009	0.010	-0.004	-0.001	-0.005
	(0.024)	(0.024)	(0.010)	(0.008)	(0.024)	(0.024)	(0.011)	(0.009)
Panel E: Risk Literacy								
Test passed	-0.033	0.051*	-0.008	-0.010	-0.037	0.048*	-0.006	-0.005
	(0.023)	(0.021)	(0.010)	(0.009)	(0.024)	(0.023)	(0.010)	(0.009)
Number of observations	1,422	616	80	62	1,422	616	80	62

Note: Robust standard errors are reported in parentheses.
** and * indicate statistical significance at the 1% and 5% level, respectively.

D Appendix: Robustness checks

Table A4: Marginal effects of Multinomial Logit models on the willingness to get vaccinated in July/August 2021

	Willingness to get vaccinated							
	Separate models				**Combined model**			
	Willing		**Hesistant**		**Willing**		**Hesistant**	
	Vaccinated	Willing	Waiting	Unwilling	Vaccinated	Willing	Waiting	Unwilling
Panel A: Reactance								
Medium	-0.009	0.002	0.009*	-0.002	-0.009	0.002	0.009*	-0.002
	(0.009)	(0.006)	(0.005)	(0.004)	(0.009)	(0.006)	(0.005)	(0.004)
High	-0.073**	0.002	0.029**	0.043**	-0.071**	0.000	0.028**	0.043**
	(0.011)	(0.006)	(0.006)	(0.008)	(0.011)	(0.006)	(0.006)	(0.008)
Panel B: Neuroticism								
Medium	-0.009	0.014*	0.004	-0.008	-0.001	0.013*	0.000	-0.012
	(0.014)	(0.006)	(0.007)	(0.010)	(0.014)	(0.006)	(0.008)	(0.010)
High	0.013	0.004	0.004	-0.021*	0.022	0.004	0.000	-0.025**
	(0.012)	(0.004)	(0.007)	(0.009)	(0.012)	(0.004)	(0.007)	(0.009)
Panel C: Locus of Control								
Medium	-0.005	0.010	0.001	-0.007	-0.004	0.010	0.003	-0.009
	(0.012)	(0.006)	(0.008)	(0.008)	(0.012)	(0.005)	(0.007)	(0.008)
High	0.014	0.001	-0.009	-0.005	0.012	0.001	-0.005	-0.008
	(0.011)	(0.004)	(0.007)	(0.008)	(0.011)	(0.004)	(0.006)	(0.008)
Panel D: Health Literacy								
Low	0.011	-0.005	-0.002	-0.004	0.011	-0.005	-0.002	-0.004
	(0.011)	(0.004)	(0.007)	(0.007)	(0.011)	(0.004)	(0.007)	(0.007)
Panel E: Risk Literacy								
Test passed	0.008	0.002	-0.002	-0.008	0.010	0.002	-0.002	-0.009
	(0.012)	(0.005)	(0.007)	(0.009)	(0.011)	(0.005)	(0.007)	(0.008)
Number of observations	2,062	23	40	55	2,062	23	40	55

Note: Robust standard errors are reported in parentheses.
** and * indicate statistical significance at the 1% and 5% level, respectively.

Table A5: Marginal effects of Multinomial Logit models on the willingness to get vaccinated in October/November 2021

	Willingness to get vaccinated							
	Separate models				**Combined model**			
	Willing		**Hesistant**		**Willing**		**Hesistant**	
	Vaccinated	Willing	Waiting	Unwilling	Vaccinated	Willing	Waiting	Unwilling
Panel A: Reactance								
Medium	-0.013*	-0.001	0.011*	0.003	-0.009	-0.005	0.011*	0.003
	(0.006)	(0.003)	(0.005)	(0.002)	(0.008)	(0.007)	(0.005)	(0.002)
High	-0.057**	-0.002	0.019**	0.041**	-0.054**	-0.006	0.020**	0.040**
	(0.008)	(0.002)	(0.005)	(0.006)	(0.011)	(0.006)	(0.005)	(0.008)
Panel B: Neuroticism								
Medium	0.006	-0.002	-0.002	-0.002	0.012	-0.003	-0.003	-0.005
	(0.011)	(0.002)	(0.008)	(0.008)	(0.011)	(0.002)	(0.007)	(0.009)
High	0.019	-0.001	-0.009	-0.008	0.023*	-0.002	-0.010	-0.011
	(0.010)	(0.002)	(0.007)	(0.008)	(0.010)	(0.002)	(0.006)	(0.008)
Panel C: Locus of Control								
Medium	-0.006	0.003	0.005	-0.002	-0.008	0.005	0.004	-0.001
	(0.010)	(0.002)	(0.006)	(0.008)	(0.010)	(0.003)	(0.006)	(0.007)
High	0.003	0.000	0.004	-0.007	0.001	-0.000	0.003	-0.005
	(0.009)	(0.000)	(0.006)	(0.007)	(0.009)	(0.000)	(0.005)	(0.007)
Panel D: Health Literacy								
Low	0.007	-0.001	0.000	-0.006	0.007	-0.002	0.000	-0.006
	(0.008)	(0.001)	(0.006)	(0.006)	(0.009)	(0.001)	(0.006)	(0.006)
Panel E: Risk Literacy								
Test passed	0.008	0.001	-0.008	-0.000	0.009	0.001	-0.008	-0.002
	(0.010)	(0.001)	(0.007)	(0.007)	(0.009)	(0.001)	(0.005)	(0.007)
Number of observations	2,105	2	31	42	2,105	2	31	42

Note: Robust standard errors are reported in parentheses.
** and * indicate statistical significance at the 1% and 5% level, respectively.

Table A6: Marginal effects of Multinomial Logit models on the willingness to get vaccinated in May 2021 – larger cross-sectional sample

	Willingness to get vaccinated							
	Separate models				**Combined model**			
	Willing		**Hesistant**		**Willing**		**Hesistant**	
	Vaccinated	Willing	Waiting	Unwilling	Vaccinated	Willing	Waiting	Unwilling
Panel A: Reactance								
Medium	-0.006	-0.004	0.008	0.003	-0.008	-0.002	0.007	0.003
	(0.022)	(0.022)	(0.006)	(0.004)	(0.022)	(0.022)	(0.007)	(0.004)
High	-0.078**	-0.028	0.050**	0.056**	-0.077**	-0.026	0.048**	0.055**
	(0.021)	(0.021)	(0.008)	(0.007)	(0.021)	(0.021)	(0.008)	(0.007)
Panel B: Neuroticism								
Medium	0.036	-0.030	0.021*	-0.027**	0.048*	-0.025	0.016	-0.039**
	(0.021)	(0.020)	(0.009)	(0.010)	(0.021)	(0.021)	(0.009)	(0.012)
High	0.017	0.005	0.011	-0.032**	0.036	0.008	0.003	-0.047**
	(0.021)	(0.021)	(0.008)	(0.010)	(0.023)	(0.022)	(0.009)	(0.012)
Panel C: Locus of Control								
Medium	0.024	-0.013	-0.006	-0.006	0.021	-0.010	-0.003	-0.008
	(0.021)	(0.020)	(0.010)	(0.008)	(0.021)	(0.021)	(0.009)	(0.009)
High	0.039	-0.003	-0.023**	-0.013	0.036	-0.003	-0.015	-0.018*
	(0.020)	(0.020)	(0.009)	(0.008)	(0.022)	(0.021)	(0.008)	(0.008)
Panel D: Health Literacy								
Low	0.023	-0.033	0.009	0.001	0.019	-0.028	0.007	0.001
	(0.019)	(0.018)	(0.009)	(0.007)	(0.019)	(0.018)	(0.009)	(0.007)
Panel E: Risk Literacy								
Test passed	-0.028	0.042*	-0.005	-0.009	-0.027	0.036	-0.003	-0.006
	(0.020)	(0.019)	(0.009)	(0.008)	(0.020)	(0.020)	(0.008)	(0.007)
Number of observations	1,834	862	109	88	1,834	862	109	88

Note: Robust standard errors are reported in parentheses.
** and * indicate statistical significance at the 1% and 5% level, respectively.

Table A7: Marginal effects of Multinomial Logit models on the willingness to get vaccinated in May 2021 – pooled sample

	Willingness to get vaccinated							
	Separate models				**Combined model**			
	Willing		**Hesistant**		**Willing**		**Hesistant**	
	Vaccinated	Willing	Waiting	Unwilling	Vaccinated	Willing	Waiting	Unwilling
Panel A: Reactance								
Medium	-0.011	0.000	0.010*	0.001	-0.009	-0.001	0.009**	0.001
	(0.010)	(0.009)	(0.005)	(0.003)	(0.011)	(0.010)	(0.003)	(0.002)
High	-0.074**	-0.004	0.031**	0.046**	-0.071**	-0.006	0.031**	0.046**
	(0.011)	(0.008)	(0.005)	(0.006)	(0.011)	(0.010)	(0.004)	(0.004)
Panel B: Neuroticism								
Medium	0.005	-0.002	0.004	-0.007	0.014	-0.003	0.000	-0.011*
	(0.013)	(0.008)	(0.007)	(0.009)	(0.011)	(0.009)	(0.005)	(0.006)
High	0.011	0.005	-0.001	-0.016*	0.025*	0.002	-0.005	-0.022**
	(0.012)	(0.008)	(0.006)	(0.008)	(0.011)	(0.010)	(0.005)	(0.005)
Panel C: Locus of Control								
Medium	0.009	-0.003	0.002	-0.008	0.006	-0.001	0.002	-0.008
	(0.012)	(0.008)	(0.007)	(0.008)	(0.011)	(0.010)	(0.005)	(0.005)
High	0.023*	-0.007	-0.007	-0.009	0.018	-0.005	-0.004	-0.009
	(0.011)	(0.008)	(0.006)	(0.007)	(0.011)	(0.010)	(0.004)	(0.005)
Panel D: Health Literacy								
Low	0.013	-0.009	-0.001	-0.004	0.011	-0.007	-0.001	-0.003
	(0.011)	(0.007)	(0.006)	(0.007)	(0.010)	(0.009)	(0.004)	(0.004)
Panel E: Risk Literacy								
Test passed	-0.005	0.018*	-0.006	-0.007	0.000	0.014	-0.007	-0.008
	(0.012)	(0.007)	(0.007)	(0.008)	(0.010)	(0.009)	(0.004)	(0.004)
Number of observations	5,589	641	151	159	5,589	641	151	159

Note: Robust standard errors are reported in parentheses.
** and * indicate statistical significance at the 1% and 5% level, respectively.

Table A8: Marginal effects of Probit models on the willingness to get vaccinated in May 2021

	Vaccination status (yes/no)	
	Separate models	**Combined model**
Panel A: Reactance		
Medium	-0.014	-0.012
	(0.024)	(0.024)
High	-0.094**	-0.089**
	(0.023)	(0.024)
Panel B: Neuroticism		
Medium	0.017	0.028
	(0.023)	(0.024)
High	0.001	0.020
	(0.022)	(0.024)
Panel C: Locus of Control		
Medium	0.040	0.034
	(0.023)	(0.024)
High	0.052*	0.044
	(0.022)	(0.024)
Panel D: Health Literacy		
Low	0.019	0.012
	(0.021)	(0.021)
Panel E: Risk Literacy		
Test passed	-0.036	-0.033
	(0.022)	(0.023)

Note: Robust standard errors are reported in parentheses.
** and * indicate statistical significance at the 1% and 5% level, respectively. Number of observations: 2,180.

Table A9: Coefficients of Accelerated Failure Time models (Log-Logistic distribution) on the time until vaccination

	(1)	(2)	(3)	(4)	(5)	(6)
Medium Reactance	0.007	–	–	–	–	0.007
	(0.012)	–	–	–	–	(0.012)
High Reactance	0.061**	–	–	–	–	0.060**
	(0.011)	–	–	–	–	(0.012)
Medium Neuroticism	–	-0.002	–	–	–	-0.010
	–	(0.012)	–	–	–	(0.012)
High Neuroticism	–	-0.006	–	–	–	-0.016
	–	(0.011)	–	–	–	(0.012)
Medium Locus of Control	–	–	-0.016	–	–	-0.015
	–	–	(0.012)	–	–	(0.012)
High Locus of Control	–	–	-0.021*	–	–	-0.016
	–	–	(0.011)	–	–	(0.012)
Mdium/High Health Literacy	–	–	–	0.000	–	-0.002
	–	–	–	(0.011)	–	(0.011)
Berlin Test passed	–	–	–	–	0.012	0.011
	–	–	–	–	(0.011)	(0.011)
University degree	-0.046**	-0.047**	-0.045**	-0.047**	-0.049**	-0.047**
	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)
Female	-0.012	-0.013	-0.014	-0.014	-0.013	-0.009
	(0.009)	(0.010)	(0.009)	(0.010)	(0.009)	(0.010)
$80 >$ Age ≥ 70	0.181**	0.174**	0.178**	0.175**	0.175**	0.182**
	(0.029)	(0.028)	(0.028)	(0.028)	(0.028)	(0.029)
$70 >$ Age ≥ 60	0.223**	0.218**	0.222**	0.218**	0.217**	0.222**
	(0.029)	(0.029)	(0.029)	(0.029)	(0.029)	(0.029)
Age ≤ 60	0.339**	0.339**	0.342**	0.339**	0.336**	0.338**
	(0.029)	(0.028)	(0.028)	(0.028)	(0.028)	(0.029)
Constant	1.431**	1.465**	1.472**	1.462**	1.461**	1.449**
	(0.029)	(0.028)	(0.028)	(0.029)	(0.027)	(0.031)
$ln(\gamma)$	-1.975**	-1.970**	-1.970**	-1.969**	-1.970**	-1.976**
	(0.027)	(0.027)	(0.027)	(0.027)	(0.027)	(0.027)

Note: Robust standard errors are reported in parentheses. ** and * indicate statistical significance at the 1% and 5% level, respectively. Number of observations: 2,180.

Table A10: Coefficients of Accelerated Failure Time models (Weibull distribution) on the time until vaccination – accounting for interval censoring

	(1)	(2)	(3)	(4)	(5)	(6)
Medium Reactance	0.024	–	–	–	–	0.023
	(0.015)	–	–	–	–	(0.015)
High Reactance	0.112**	–	–	–	–	0.112**
	(0.015)	–	–	–	–	(0.015)
Medium Neuroticism	–	0.015	–	–	–	0.005
	–	(0.017)	–	–	–	(0.016)
High Neuroticism	–	-0.010	–	–	–	-0.019
	–	(0.015)	–	–	–	(0.015)
Medium Locus of Control	–	–	0.002	–	–	0.008
	–	–	(0.017)	–	–	(0.016)
High Locus of Control	–	–	-0.021	–	–	-0.008
	–	–	(0.016)	–	–	(0.015)
High Health Literacy	–	–	–	0.005	–	0.001
	–	–	–	(0.015)	–	(0.014)
Berlin Test passed	–	–	–	–	0.012	0.015
	–	–	–	–	(0.017)	(0.016)
University degree	-0.053**	-0.056**	-0.052**	-0.055**	-0.057**	-0.057**
	(0.013)	(0.014)	(0.014)	(0.014)	(0.014)	(0.013)
Female	-0.001	-0.002	-0.004	-0.002	-0.002	0.002
	(0.012)	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)
$80 > \text{Age} \geq 70$	0.137**	0.133**	0.127**	0.131**	0.132**	0.140**
	(0.039)	(0.041)	(0.043)	(0.042)	(0.041)	(0.037)
$70 > \text{Age} \geq 60$	0.228**	0.230**	0.229**	0.229**	0.229**	0.229**
	(0.040)	(0.042)	(0.045)	(0.043)	(0.042)	(0.038)
$\text{Age} \leq 60$	0.353**	0.364**	0.357**	0.360**	0.359**	0.352**
	(0.038)	(0.040)	(0.042)	(0.042)	(0.041)	(0.037)
Constant	1.411**	1.466**	1.479**	1.466**	1.467**	1.413**
	(0.037)	(0.039)	(0.041)	(0.040)	(0.038)	(0.037)
$ln(p)$	1.420**	1.397**	1.397**	1.396**	1.396**	1.422**
	(0.023)	(0.024)	(0.024)	(0.024)	(0.023)	(0.023)

Note: Robust standard errors are reported in parentheses. ** and * indicate statistical significance at the 1% and 5% level, respectively. Number of observations: 2,180.

Table A11: Coefficients of Accelerated Failure Time models (Weibull distribution) on the time until vaccination – omitting unvaccinated individuals

	(1)	(2)	(3)	(4)	(5)	(6)
Medium Reactance	0.011	–	–	–	–	0.011
	(0.011)	–	–	–	–	(0.011)
High Reactance	0.034**	–	–	–	–	0.034**
	(0.010)	–	–	–	–	(0.010)
Medium Neuroticism	–	-0.006	–	–	–	-0.010
	–	(0.010)	–	–	–	(0.011)
High Neuroticism	–	-0.004	–	–	–	-0.008
	–	(0.010)	–	–	–	(0.010)
Medium Locus of Control	–	–	0.010	–	–	0.012
	–	–	(0.011)	–	–	(0.011)
High Locus of Control	–	–	-0.005	–	–	-0.001
	–	–	(0.009)	–	–	(0.010)
High Health Literacy	–	–	–	-0.010	–	-0.013
	–	–	–	(0.010)	–	(0.010)
Berlin Test passed	–	–	–	–	0.008	0.009
	–	–	–	–	(0.010)	(0.010)
University degree	-0.033**	-0.034**	-0.033**	-0.032**	-0.035**	-0.033**
	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)
Female	-0.010	-0.010	-0.012	-0.013	-0.010	-0.011
	(0.008)	(0.009)	(0.008)	(0.008)	(0.008)	(0.009)
$80 >$ Age ≥ 70	0.107**	0.106**	0.106**	0.106**	0.107**	0.105**
	(0.027)	(0.027)	(0.027)	(0.027)	(0.027)	(0.026)
$70 >$ Age ≥ 60	0.172**	0.172**	0.173**	0.174**	0.173**	0.171**
	(0.027)	(0.027)	(0.027)	(0.027)	(0.027)	(0.027)
Age ≤ 60	0.273**	0.274**	0.275**	0.277**	0.274**	0.272**
	(0.026)	(0.026)	(0.026)	(0.026)	(0.026)	(0.026)
Constant	1.554**	1.576**	1.572**	1.578**	1.571**	1.565**
	(0.026)	(0.026)	(0.025)	(0.026)	(0.026)	(0.027)
$ln(p)$	1.695**	1.692**	1.693**	1.692**	1.692**	1.698**
	(0.022)	(0.022)	(0.021)	(0.021)	(0.021)	(0.021)

Note: Robust standard errors are reported in parentheses. ** and * indicate statistical significance at the 1% and 5% level, respectively. Number of observations: 2,062.