Psychological correlates of attitudes towards COVID-19 vaccines among Polish respondents – a snapshot study before the start of a massive vaccination campaign

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ABSTRACT

Aim

COVID-19 vaccines are recognized as a way to stop the ongoing pandemic. However, for this method to be effective, a large population must be willing to be vaccinated. The aim of this study was to measure the psychological underpinnings of attitudes towards vaccination against COVID-19 at a time when the vaccine had been developed, but not yet distributed among Polish citizens.

Method

An online survey study was conducted on a sample of 468 Polish participants. We used questionnaires to measure attitudes towards the COVID-19 vaccine, fear of COVID, general tendency to conspiracy ideation and conspiracy beliefs about COVID-19, knowledge about vaccines, attitudes towards science, previous protective behaviors during the pandemic, perceived infectability, and germ avoidance. We also tested the associations between attitudes towards the COVID-19 vaccine and the participants' experiences of the COVID-19 pandemic, gender, age, and level of education.

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Results

The analyses revealed correlations between attitudes towards the COVID-19 vaccine and most of the studied variables. A regression model with predictors such as fear of COVID, attitudes towards science and conspiracy beliefs related to COVID-19 explained 46% of the variance in attitudes towards the COVID-19 vaccine. Male participants were more positive about the COVID-19 vaccine than female participants. Attitudes towards the COVID-19 vaccine were not related to the participants' personal experiences of the pandemic, age or level of education.

Conclusion

The obtained results show the importance of the psychological underpinnings of attitudes towards vaccination which can be considered in designing future preventive public interventions.

Keywords: attitudes towards COVID-19 vaccination, attitudes towards science, COVID-19 pandemic, psychological contexts of attitudes towards COVID-19 pandemic, conspiracist ideation.

INTRODUCTION

The ongoing COVID-19 pandemic is a severe challenge for the global healthcare system (Blumenthal, Fowler, Abrams, & Collins, 2020). One possible route to stop the pandemic is related to vaccines against the SARS-CoV-2 virus (European Centre for Disease Prevention and Control, 2020). However, for this method to be effective, it requires a high level of public acceptance of the vaccine and people's willingness to be vaccinated (Böhm, Meier, Groß, Korn, & Betsch, 2019; Vietri, Galvani, & Chapman, 2012).

Studies conducted before the COVID-19 pandemic have shown that the level of vaccination acceptance may be influenced by factors such as perceived belonging to a risk group and concerns about safety, especially related to side effects (Trim, Nagji, Elit, & Roy, 2012). Research conducted in Poland in 2018–2019 shows that a positive attitude to vaccination is associated with older age, higher knowledge about vaccines, obtaining information on vaccination from doctors, and the conviction that this information is of high quality (Czajka, Czajka, Biłas, Pałka, Jędrusik, &, Czapkiewicz, 2020; for definition of attitude see: APA Dictionary of Psychology, n.d.). Studies conducted during the COVID-19 pandemic show that vaccination readiness is increased by education, having insurance, scoring high on subjective importance of norms, high perceived susceptibility to COVID-19, high perceived benefits of the vaccine, scoring high on self-efficacy, and scoring low on barriers to the vaccine (Guidry et al., 2020). Research conducted by Giuliani et al. (2021) showed that respondents willing to vaccinate against COVID-19 had a higher level of fear of COVID-19 infection for themselves, their families and their friends. Belief in conspiracy theories about the origin of the virus, perceived low level of health risks posed by the virus, and doubt in goals underlying the development of the vaccine may also decrease the acceptance of COVID-19 vaccines (Bertin, Nera, & Delouvée, 2020; Earnshaw et al., 2020). Reluctance to vaccinate

may also express a general lack of confidence in science (Giuliani et al., 2021; Lewandowsky, Gignac, & Oberauer, 2013; Plohl & Musil, 2021).

Aims of the study and research hypotheses

The aim of this study was to identify the possible psychological contexts of attitudes towards COVID-19 vaccination in the Polish sample. We measured the following variables: fear of COVID (Ahorsu et al., 2020; Pilch, Kurasz, & Turska-Kawa, 2021), pandemic-related behavior (Imhoff & Lamberty, 2020), tendency to perceive COVID-19 as a hoax or a result of deliberate action (Imhoff & Lamberty, 2020), the general tendency for conspiracist ideation (Brotherton, French, & Pickering, 2013), attitudes towards science (Jach, 2019, 2021) and perceived infectability and germ avoidance (Duncan, Shaller, & Park, 2009; Makhanova & Shepherd, 2020). For this study, we also designed a tool to test knowledge about COVID-19 and vaccinations. We also asked participants for their experiences related to the COVID-19 pandemic.

Based on the results of the research mentioned in the introduction, we formulated the following hypotheses:
- – H1: Participants with COVID-19-related experiences would display more positive attitudes towards the COVID-19 vaccine.
- – H2: Attitudes towards the vaccine would positively correlate with the fear of COVID, previous protective behaviors during the pandemic, knowledge about vaccines, and positive attitudes towards science.
- – H3: Positive attitudes towards vaccines would negatively correlate with the level of belief in the COVID-19 conspiracies and the general level of conspiracist ideation.

Additionally, we performed a regression analysis to test to what extent the variables included in the study were suitable for predicting attitudes towards COVID-19 vaccination. We also measured the relationships between attitudes towards the COVID-19 vaccine with gender, age, and the education level of the respondents.

METHOD

Participants and procedure

We conducted the study from 30 November to 9 December 2020. During this period, the media had already reported the development of the first vaccines against COVID-19, but these vaccines had not yet been distributed (in Poland, vaccinations started on 27 December 2020). The data were collected among Polish participants using an electronic survey module (Lime Survey). Participants were recruited using snowball sampling among students and on social media. Participation in the study was anonymous, voluntary, and without monetary

compensation. Before filling the questionnaire, the participants read the instructions describing the purpose of the procedure. Data was obtained only from participants who gave their informed written consent. The design was approved by the Ethics Committee of the University of Silesia (decision number: KEUS.66/11.2020).

Four hundred and sixty-eight respondents took part in the research (218 male, 248 female, and two people who declared another gender), aged 18 to 70 ($M = 31.23$; $SD = 11.05$). Six participants declared the education level below the secondary level, 231 declared the secondary level, and 231 declared the completed education at the university level. The groups of male and female participants did not differ in terms of age ($t(464) = 1.66$; $p = .10$) and level of education ($\chi^2(2) = 3.40$; $p = .18$). Descriptive statistics related to all measured variables are presented in Table 1.

Table 1

Descriptive statistics of quantitative variables in the study

Quantitative variable	Mean	Std. Deviation	Skewness	Kurtosis	Median	Lower quartile	Upper quartile	Shapiro-Wilk W	Shapiro-Wilk p-value
Age (years)	31.23	11.05	.94	.29	29	22	37	.91	< .001
Attitudes towards COVID-19 vaccine	21.30	9.16	-.20	-1.23	22	14	29	.94	< .001
Fear of COVID	14.35	4.68	.53	.34	14	11	18	.97	< .001
Containment-related behavior	38.55	7.63	-1.35	2.33	40	35	44	.90	< .001
Self-centered prepping behavior	6.92	3.20	2.37	8.91	6	5	8	.78	< .001
Perceived infectability	25.46	8.14	.40	-.02	25	20	30	.99	< .001
Germ aversion	36.29	8.64	-.06	-.38	36	30	43	.99	.082
Attitudes towards science	52.24	11.79	-.17	-.16	52	44.5	60	.99	.071
Conspiracist ideation	34.70	11.91	.43	-.48	33	25	43	.97	< .001
COVID-19 hoax	7.284	4.56	1.10	.55	6	3	10	.86	< .001
SARS-CoV-2 human made	7.59	4.05	.96	.56	7	4	10	.91	< .001
Knowledge about vaccines	8.38	2.16	-.20	-.36	8	7	10	.98	< .001

Measures

To collect information about the participants' experiences related to the COVID-19 pandemic, we asked five questions to which the respondents answered "yes" or "no". The complete list of questions with the number of answers is provided in Table 2.

Table 2

Participants' experiences with the COVID-19

Question	Yes	No
Did you have COVID-19?	57 (12%)	411 (88%)
Did any of your relatives have COVID-19?	244 (52%)	224 (48%)
Did any of your relatives die of COVID-19?	19 (4%)	449 (96%)
Were you quarantined during the COVID-19 pandemic?	84 (18%)	384 (82%)
Was any of your relatives quarantined during the COVID-19 pandemic?	192 (41%)	276 (59%)

To find out about the respondents' attitudes towards COVID-19 vaccines, we asked them five questions they responded to by selecting one of seven responses from "1 – definitely not" to "7 – definitely yes" (see Supplementary Information A). The sum of the response-related points was the score of a scale for measuring attitudes towards the COVID-19 vaccine. The more points the participants scored, the more positive their attitude to the vaccine was. In the current study, the scale had satisfactory reliability: the standardized Cronbach's α coefficient was .91, the average inter-item correlation coefficient was .67, and the average item-rest correlation coefficient was .78. The exploratory factor analysis conducted with Varimax rotation showed that all the scale questions loaded one factor with an eigenvalue above 1 (3.70), explaining 74.05% of the variance (the lowest factor loading was .663). The confirmatory factor analysis (using DWLS – Diagonally Weighted Least Squares estimator) showed that this unidimensional model was characterized by not fully satisfactory fit indices: $\chi2/df$ = 5.77; root mean square error of approximation (RMSEA) = .10 [90% C.I.: .07 – .14]; goodness of fit index (GFI) = .99; comparative fit index (CFI) = .99; standardized root mean squared residual (SRMR) = .05. However, the analysis of the modification indices showed a covariance of the residuals between items 4 and 5, both relating to the issue of the mandatory vaccine in the different groups. After including this covariance, the model had satisfactory fit indices: $\chi2/df$ = .186; RMSEA < .001 [90% C.I.: .00 – .01]; GFI > .99; CFI > .99; SRMR = .01.

The level of COVID-19-related anxiety was measured using The Fear of COVID Scale (Ahorsu et al., 2020) in the Polish adaptation by Pilch, Kurasz, and Turska-Kawa (2021). It consists of seven statements (e.g., "I am most afraid of coronavirus-19."), to which the participants responded by selecting one of the

five answers arranged on a scale from "1 – strongly disagree" to "5 – strongly agree". Higher scores on this scale indicate a higher level of anxiety related to COVID-19. In the procedure performed, the standardized Cronbach's α coefficient of the described scale was .82.

To measure pandemic-related behaviors, we used a set of statements designed by Imhoff and Lamberty (2020). In each of them, respondents chose one of seven answers: from "1 – never" to "7 – always / strongly". These statements group into two scales that measure containment-related behavior (items 1–6; e.g., "Avoiding social contacts.") and self-centered prepping behavior (items 9–17; e.g. "Withdrawing available cash from my bank account."). There are also two items (7 and 8) that cannot be strictly related to these scales. In the current study, the reliability of the factors developed in this way was relatively low (standardized Cronbach's α coefficients respectively: .79 and .61); therefore, we decided to conduct an exploratory factor analysis using Varimax rotation. This analysis revealed two factors with an eigenvalue above 1, including a total of 11 items with factor loadings above .400. The first one contained all six items originally belonging to the containment-related behavior dimension, and one item initially related to the different dimension ("Wearing protective face masks out of the house"). The second dimension contained four items originally belonging to the self-centered prepping behavior (items 9–12). Four items were not related to any dimension (factor loadings below .40), and items 7 and 8 loaded both dimensions (the same as in Imhoff and Lamberty's research). After removing unrelated and ambiguous items, two reliable dimensions emerged (standardized Cronbach's α coefficients, respectively .81 and .76), explaining in total 52.94% of the variance. The confirmatory factor analysis (using DWLS estimator) showed that the two-factor model was characterized by satisfactory fit indices: $\chi 2/df$ = 1.62; RMSEA = .04 [90% C.I.: .02 – .05]; GFI = .97; CFI = .97; SRMR = .07.

Perceived infectability and germ avoidance were measured using the PVD questionnaire (Duncan et al., 2009). We modified item 15 according to the amendment introduced by Makhanova and Shepherd (2020). The tool consists of 15 statements with seven possible responses: from "1 – strongly disagree" to "7 – strongly agree". Seven of these statements built the scale that measures perceived infectability (e.g. "In general, I am very susceptible to colds, flu and other infectious diseases."), and the remaining eight build the scale that measures germ aversion tendency (e.g. "I prefer to wash my hands pretty soon after shaking someone's hand."). In the presented study, the standardized Cronbach's α of the perceived infectability scale was .85, and in the case of the germ aversion scale, it was .69. The confirmatory factor analysis (using DWLS estimator) showed that the two-factor model was characterized by satisfactory fit indices: $\chi 2/df$ = 2.26; RMSEA = .05 [90% C.I.: .04 – .06]; GFI = .98; CFI = .96; SRMR = .07.

We measured attitudes towards science using the Views of Science Questionnaire (Jach, 2019, 2021). The tool consists of 16 items (e.g. "Scientific theories are based on indisputable foundations.") to which the participants respond by selecting options arranged on a scale from "1 – strongly disagree" to "5 – strongly agree". The statements of the questionnaire refer to such aspects related to

attitudes towards science as trust in a scientific method perceiving scientists as the most competent experts, recognizing science as a tool of practical influence on the environment, and hope for a better future. The higher is the score obtained, the more positive attitudes towards science are. In the current study, the standardized Cronbach's α coefficient for this tool was .89.

We measured the general tendency to conspiracist ideation using the Generic Conspiracist Beliefs Scale (Brotherton, French, & Pickering, 2013) in the Polish adaptation by Siwiak, Szpitalak, and Polczyk (2019). This scale consists of 15 statements (e.g. "A small, secret group of people is responsible for making all major world decisions, such as going to war.") that one may respond to by selecting one of the options on a scale from "1 – definitely not true" to "5 – definitely true". Higher scores on this scale indicate a stronger general tendency to entertain conspiracist beliefs. In the present study, the standardized Cronbach's α of this scale was .93.

The tendency to entertain specific conspiracy beliefs relating to the COVID-19 pandemic was measured using the six statements proposed by Imhoff and Lamberty (2020). Three of them are related to the opinion that the COVID-19 pandemic is a hoax (e.g. "The virus is intentionally presented as dangerous in order to mislead the public."), and the other three are related to the opinion that the SARS-CoV-2 virus was human-made (e.g. "Dark forces want to use the virus to rule the world"). These statements can be assessed by choosing one of seven options, arranged on a scale from "1 – strongly disagree" to "7 – strongly agree". The more points one obtains, the more conspiratorial their thinking about the COVID-19 pandemic is. In the presented study, the standardized Cronbach α coefficient of the COVID-19 hoax scale was .89, and in the case of the SARS-CoV-2 human-made scale was .75. The confirmatory factor analysis (using DWLS estimator) showed that the two-factor model was characterized by satisfactory fit indices: $\chi 2/df$ = .73; RMSEA < .001 [90% C.I.: .00 – .04]; GFI < 1.00; CFI = 1.00; SRMR = .03.

We tested the participants' knowledge about the SARS-Cov-2 virus, vaccines in general, and the COVID-19 vaccine, using a test designed specifically for this purpose (see Supplementary Information B). It consists of 13 questions, which one answers by selecting 1 out of 4 possible options (one correct, three incorrect). The score is the number of correct answers. Due to the binomial nature of each question's possible scores, the Cronbach's α coefficient for this tool was calculated based on tetrachoric correlations. The value of the standardized Cronbach's α was .80.

Data analysis

We used Version 13.3 of Statistica (TIBCO Software Inc., 2017) and Version 0.14.1.0 of JASP (JASP Team, 2020) for statistical analysis. Due to the non-normality of distribution of the most studied quantitative variables (see Table 1), we used non-parametric tests, i.e., the Mann-Whitney U test and the Spearman rho correlation test. We also performed a linear regression analysis. A p-value below .05 was considered statistically significant.

RESULTS

COVID-19 pandemic related experiences and attitudes towards COVID-19 vaccines

To test Hypothesis 1, we checked if the participants' COVID-19 pandemic-related experiences were related to their attitudes towards the COVID-19 vaccine. For this purpose, we conducted a series of Mann-Whitney U tests. There was no relationship between attitudes towards the COVID-19 vaccine and having COVID-19 history (corrected $Z = -1.11$; $p = .268$), having relatives with COVID-19 history (corrected $Z = -1.35$; $p = .178$), having relatives who died on COVID-19 (corrected $Z = -1.03$; $p = .304$), being quarantined during the COVID-19 (corrected $Z = -.50$; $p = .620$) and having relatives who were quarantined during the COVID-19 pandemic (corrected $Z = -.47$; $p = .638$). The obtained results lead to the rejection of the hypothesis that participants who have personal experiences related to COVID-19 would have more positive attitudes towards COVID-19 vaccines.

Psychological contexts of attitudes towards the COVID-19 vaccine

To test Hypotheses 2 and 3, we conducted the correlation analyses using Spearman rho coefficients. Most postulated relationships between the attitudes towards the COVID-19 vaccine and the psychological variables studied have been confirmed. The inconsistent result was only the lack of association between attitudes towards the COVID-19 vaccine and self-centered prepping behavior (rho(464) = .06; $p = .168$).

Attitudes towards the COVID-19 vaccine were positively associated with the fear of COVID (rho(464) = .28; $p < .001$), containment-related behavior (rho(464) = .37; $p < .001$), perceived infectability (rho(464) = .16; $p < .001$), germ aversion (rho(464) = .15; $p < .001$), attitudes towards science (rho(464) = .44; $p < .001$), and knowledge about vaccines (rho(464) = .13; $p = .004$). Attitudes towards the COVID-19 vaccine were also negatively associated with the general tendency to conspiracist ideation (rho(464) = -41; $p < .001$) and conspiracist beliefs related to the COVID-19 pandemic: belief that COVID-19 was a hoax (rho(464) = -.58; $p < .001$) and belief that SARS-CoV was human-made (rho(464) = -.43; $p < .001$).

Predictors of attitudes towards the COVID-19 vaccine

One of the issues addressed in the present study was identifying predictors of attitudes towards the COVID-19 vaccine. For this purpose, we conducted a multiple regression analysis, in which we introduced variables showing significant correlations with attitudes of the COVID-19 vaccine as possible predictors. The analysed model turned out to be significant ($F(9, 458) = 43.35$; $p < .001$), and the adjusted R^2 coefficient was .45. However, analysis of the residuals showed outlier data from one participant (standardized residual = -3.08). When we removed

data obtained from this participant from the analysis, the regression model was still statistically significant: $F(9, 457) = 44.59$; $p < .001$, and the adjusted R^2 coefficient was .46 (see Supplementary Information C). The value of the Durbin-Watson statistic was 2.00, which indicated no residual autocorrelation.

Since many correlates were not significant predictors of attitudes towards the COVID-19 vaccine, we decided to check whether a shorter list of predictors would result in a model with a comparable level of explained variance of the dependent variable. As a result of the progressive stepwise regression analysis, the fitted model ($F(4, 462) = 100.10$) was obtained, containing four predictors. The adjusted R^2 coefficient for this model was .46. Detailed information on the shortened model is presented in Table 3.

Table 3

Progressive stepwise regression analysis of attitudes towards the COVID-19 vaccine – the final, shortened model

Predictor	Beta	B	Standard error	$t(458)$
Intercept		14.80	2.10	7.064***
Covid-19 hoax	-.40	-.80	.09	-8.886***
Attitudes towards science	.27	.21	.03	7.462***
Fear of COVID	.14	.28	.07	3.969***
Sars-CoV-2 human made	-.15	-.33	.10	-3.471***

*** $p < .001$

Demographic contexts of attitudes towards COVID-19 pandemic and COVID-19 vaccine

In our study, we focused on the psychological aspects related to attitudes towards the COVID-19 vaccine. However, we extended the analyses to include links between attitudes towards the vaccine with demographic variables related to gender, age, and education level. Due to the very small samples of participants indicating gender other than male or female ($n = 2$) and participants with lower than secondary education ($n = 6$), these people were not included in the comparisons.

The Mann-Whitney U test (corrected $Z(1) = 3.30$; $p < .001$; rank biserial correlation coefficient = .18) showed that male participants (mean = 22.76; mean rank = 255.43) had more positive attitudes towards the COVID-19 vaccine than female participants (mean = 20.01; mean rank = 214.22).

Correlation analysis did not show a significant relationship between the age of the participants and their attitudes towards the COVID-19 vaccine: rho(464) = -.04; $p = .366$. There were also no differences in attitudes towards the COVID-19 vaccine between participants with secondary level and university level of education: Mann-Whitney U test corrected $Z(1) = .36$; $p = .721$; rank biserial correlation coefficient = .02.

DISCUSSION

Demographic and experiential aspects
of attitudes towards the COVID-19 vaccine

In line with other related works (Detoc et al., 2020; Guidry et al., 2020; Reiter, Pennell, & Katz, 2020), our study showed that male participants had more positive attitudes towards the COVID-19 vaccine than female participants. Previous research in Poland has shown that older people have more positive attitudes towards vaccination (Czajka et al., 2020). However, in our study, age did not correlate with attitudes towards the COVID-19 vaccine. Similar results were obtained in studies conducted by Guidry et al. (2020), but studies conducted by Reiter, Pennell, & Katz (2020) and Detoc et al. (2020) showed that older people are more willing to be vaccinated against COVID-19.

Unlike previous results (Guidry et al., 2020; Reiter, Pennell, & Katz, 2020), attitudes towards the COVID-19 vaccine in our study were not related to the education level. These differences may result from the fact that we compared only people with the secondary and university levels of education. On the other hand, according to Eurostat (n.d.) data, in 2020, 93% of people aged 25–64 in Poland had education equal to or higher than upper-secondary. It suggests that the education-related aspects related to attitudes towards the COVID-19 vaccine may not play a significant role in this case.

The personal experience of COVID-19 has not been linked to attitudes towards the COVID-19 vaccine. It suggests that the search for factors relevant to attitudes towards COVID-19 and COVID-19vaccines should focus on other aspects, such as psychological or socio-environmental.

Correlates and predictors of attitudes towards the COVID-19 vaccines

The positive correlates of attitudes towards the COVID-19 vaccine were fear of COVID, perceived infectability, germ aversion, attitudes towards science, and containment-related behavior. Knowledge about vaccines also showed positive associations with the attitudes studied. On the other hand, both general conspiracist ideation and conspiracist beliefs related to the ongoing pandemic were negatively correlated with attitudes towards the COVID-19 vaccine.

Our finding that fear of COVID-19 was positively correlated with attitudes towards vaccination was in line with previous research. Szmyd et al. (2021a, 2021b) showed that fear of contracting COVID-19 and fear of passing the disease to relatives were correlated with the willingness to vaccinate. Fischer et al. (2020) found that the willingness to get vaccinated is highest among those who believe they are likely to contract COVID-19 and get seriously ill. Of interest might be a related observation that fear of vaccination side-effects is often a negative correlate of vaccination readiness (Papagiannis et al. 2021; Szmyd et al. 2021a).

Attitudes towards vaccination were positively related to perceived infectability and germ avoidance, which are indicators of health concern. According to

Shaller and Park (2011), such care for health is related to behavioral immune system, which detects cues connoting the presence of infectious pathogens in the immediate environment, triggers disease-relevant emotional and cognitive responses, and thus facilitate behavioral avoidance of pathogen infection. In a study by Makhanova and Shepherd (2020), perceived infectability and germ avoidance were related positively to vigilance and behaviors against COVID-19 contamination. Our study showed that the level of perceived infectability and germ avoidance might also be significant in terms of attitudes towards the COVID-19 vaccine. However, previous results regarding the relationship between the behavioral immune system and vaccine intentions are ambiguous (Clay, 2017; Luz, Brown, & Struchiner, 2019).

Engagement in protective behavior is reported to be related to positive vaccination attitudes, but not always directly. Taylor, Landry, Paluszek, Rachor, and Asmundson (2020) found that the acceptance of the belief that the COVID-19 threat is exaggerated predicts disregard for social distancing and poor hand hygiene, and anti-vaccination attitudes. Vai et al. (2020) reported that unwillingness to vaccinate is related to the belief that containment measures are not efficient means to stop the spread of disease.

The correlation between attitudes towards science and vaccination readiness is confirmed by existing literature. Rutjens and van der Lee (2020) found that faith in science was a predictor of positive attitudes towards vaccines. Similar results were reported by Pivetti, Melotti, Bonomo, and Hakoköngäs (2021).

It is commonly reported that conspiracy thinking correlates with an unwillingness to vaccinate, both generally and in the specific case of COVID-19. Rutjens and van der Lee (2020) and Pivetti et al. (2021) found that conspiracy thinking was a predictor of vaccine skepticism. Bertin et al. (2020) measured attitudes towards two categories of conspiracy theories: "outgroup beliefs" and "ingroup beliefs", and found that both predict negative attitudes towards COVID-19 vaccines.

There are ambiguous reports about the correlation between the level of knowledge about COVID-19 and vaccination attitudes. Kempthorne and Terrizzi (2021) found a negative correlation between COVID-19 knowledge and anti-vaccination sentiments. Zhong et al. (2020) found a correlation between the level of knowledge about the disease and willingness to take preventive measures and avoid dangerous practices. On the other hand, Pogue et al. (2020) found no correlation between the level of knowledge and vaccination readiness.

Predictors of attitudes towards the COVID-19 vaccines

The final model of attitudes towards the COVID-19 vaccine included four predictors: fear of COVID, attitudes towards science, belief that COVID-19 was a hoax, and belief that SARS-CoV-2 was human-made. Of the variables mentioned, only attitudes towards science were a variable not directly related to the COVID-19 pandemic. It suggests that the prediction of attitudes towards the COVID-19 vaccine may be related mainly to current factors regarding how the disease is presented (e.g., in media), its causes, and the actual level of risk.

The predictive role of fear of COVID may be significant for formulating social messages about the COVID-19 vaccine. On the one hand, these messages should not contribute to spreading social unrest, but on the other hand, they should also not portray the disease too mildly. Too low level of fear of COVID could possibly lead to a reduction of preventive behavior and vaccine readiness. From a different perspective, the predictive role of the attitudes towards science and conspiratorial beliefs about COVID-19 indicates the importance of social trust in science, scientists, and political leaders. Large-scale preventive actions, such as vaccination programs, could be more effective if scientific and political messages were disseminated with greater emphasis on the dimension of public trust.

Limitations and strengths

Our study had several limitations. First, our sample consisted of volunteers and could not be representative of the general population. Volunteers who completed online questionnaires may had a high level of motivation and be more favorable to science and research. There is also a risk that people who did not trust science and scientists avoided participation in research or abandoned the procedure. However, our sample contained a comparable number of male and female participants and participants with secondary and university education levels. Moreover, the groups distinguished in terms of these variables did not differ in age. It allows the results to be considered more generalizable. While a larger sample could be more representative, our sample was adequately powered to detect even relatively small effects.

From a different perspective, there was an important reason for collecting the research sample for only ten days. Public perception of COVID-19 vaccines may change dynamically under the influence of information from the media and other people. We wanted to measure participants' attitudes when the media announced the availability of COVID-19 vaccines in the near future, but practical contexts that could influence the attitudes of participants towards the COVID-19 vaccine were absent.

Our study was based on self-report measures. There was a chance that respondents were dishonest and preferred answers which were more socially acceptable. However, self-report methods make it possible to obtain data quickly from large samples, and in our study, we wanted to collect the results within a short time between the announcement of the COVID-19 vaccine and the start of massive vaccination.

Another limitation is the use of new, not previously validated scales or *ad hoc* translations of tools that have been used in other studies in the context of the COVID-19 pandemic. It is desirable to use research tools with a high level of accuracy and cultural adaptation. The basic context for the selection of the tools used was the motivation to investigate attitudes towards COVID-19 vaccines in a short period when vaccines were already announced but were still not distributed. However, the results of the conducted reliability tests and confirmatory factor analyses supported the recognition of the obtained results as reliable.

The presented study also has some strengths. Among them, we can mention the measurement of knowledge about vaccines using a reliable, multi-topic tool. In other studies on a Polish sample (Czajka et al., 2020), knowledge about vaccination was tested with a single question. Our procedure allowed for more detailed measurements. Similarly, in our study, attitudes towards the COVID-19 vaccine were measured using a scale that applied to vaccine intentions and other aspects of vaccination (e.g., encouraging other people to the vaccine).

Another strength of the study is that it highlights the psychological variables associated with attitudes towards the COVID-19 vaccine, which may provide a more general basis for attitudes to vaccines and even general medical or scientific recommendations. Variables such as attitudes towards science, the general tendency to conspiracist ideation, germ avoidance, and perceived infectability are psychological traits that may be independent of the COVID-19 pandemic context (unlike, e.g., fear of COVID). It suggests that the development of social programs focused on educating about scientific goals and achievements, the importance of biological hazards associated with invisible agents (e.g., bacteria or viruses), and increasing the level of social trust can form the basis for more effective dealing with future problems similar to the COVID-19 pandemic.

Concluding remarks

Vaccination against COVID-19 is regarded as a crucial measure to end the ongoing pandemic. Therefore, it is vital to understand the psychological factors influencing people's attitudes towards the COVID-19 vaccine and vaccinations in general. Based on our research, the following general observations can be made:

- First, people prone to conspiracy thinking are likely to have negative attitudes towards vaccination. However, knowledge about the COVID-19 vaccine seems to be positively related to people's willingness to vaccination. Therefore, education is likely to long-term increase people's willingness to vaccinate.
- Second, attitudes towards science, including trust in the scientific method and scientists' expertise, were related to attitudes towards vaccination even more strongly than knowledge. The overall attitude towards science may be a more substantial factor influencing people's health behaviors than their actual knowledge about vaccines, infectious diseases, and COVID-19.
- Third, fear of COVID-19 was a significant predictor of positive attitudes towards vaccination. Therefore, it may be crucial how a disease is presented in the media: if it is portrayed as too benign, it may decrease people's willingness to vaccinate.

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SUPPLEMENTARY INFORMATION A

Items from the scale used to measure attitudes towards the COVID-19 vaccine (English translation)

1. Would you agree to get vaccinated with one of the recently developed vaccines against COVID-19?
2. Would you convince your family members to get vaccinated with one of the recently developed vaccines against COVID-19?
3. Would you dissuade your family members from getting vaccinated with one of the recently developed vaccines against COVID-19?
4. Do you think that a coronavirus vaccine should be mandatory for all citizens of Poland?
5. Do you think that a coronavirus vaccine should be mandatory for certain especially vulnerable citizens of Poland, such as all medical workers or people older than 65?

SUPPLEMENTARY INFORMATION B

Items used to measure the participants' knowledge about vaccines, COVID-19 and COVID-19 vaccine.
Correct answers are in bold

1. For which of these diseases is there currently **not** a vaccine available?
   a) tetanus
   b) **diabetes**
   c) poliomyelitis
   d) chickenpox
2. One of the methods for creating vaccines is "weakening" the virus, for instance, using specially chosen chemical substances. What is the name for a vaccine created this way?
   a) conjugate vaccine
   b) attenuated vaccine
   c) chemical vaccine
   d) **inactivated vaccine**
3. What is the duration of a typical clinical study of a new vaccine?
   a) less than 6 months
   b) 6 months to a year
   c) 1 year to 3 years
   d) **more than 3 years**
4. What kind of a vaccine are the newly developed vaccines against the SARS-CoV-2 virus, developed by Pfizer and Moderna companies?
   a) attenuated vaccine
   b) DNA vaccine
   c) **RNA vaccine**
   d) subunit vaccine

5. How are vaccines administrated?
    a) by oral route
    b) by intramuscular route
    c) by intranasal route
    d) **all answers are correct**
6. How many people usually participate in stage III of a clinical trial?
    a) humans do not participate in clinical trials
    b) few to a few dozens
    c) **a couple of hundreds to a few thousands**
    d) at least a hundred thousand
7. What is the name of a protein that occurs on the surface of a SARS-CoV-2 virion that is the target of many currently developed vaccines, i.e., is the component of subunit vaccines?
    a) T protein
    b) C protein
    c) K protein
    d) **S protein**
8. Which of the following components of blood is created by the organism after the vaccine has been administered and is a key component of a human immune system?
    a) insulin
    b) **immunoglobulin**
    c) integrin
    d) immunosuppressant
9. What type is the SARS-CoV-2 virus?
    a) **ssRNA**
    b) dsRNA
    c) ssDNA
    d) dsDNA
10. Which information is <u>not</u> found in the name of the SARS-CoV-2 virus after all abbreviations have been explained?
    a) information that the virus causes a disease of the respiratory system
    b) information about the family the virus belongs to
    c) **information that the virus comes from East Asia**
    d) information that the disease caused by the virus is severe
11. What is the meaning of the acronym NOP in the context of vaccines? [NOP is the Polish equivalent of VAE, *vaccine adverse effect*, and is commonly used to refer to VAEs]
    a) naturalna obrona poszczepienna [natural post-vaccination defense]
    b) niespecyficzna odpowiedź poszczepienna [non-specific post-vaccination response]
    c) nabyta odporność poszczepienna [acquired post-vaccination immunity]
    d) **niepożądany odczyn poszczepienny** [vaccine adverse effect]
12. Which of the following reactions may occur after the vaccination?
    a) redness
    b) fever

     c) malaise
     d) **all of the above**
13. What is herd immunity?
     a) an additional form of immunity that occurs only in certain species of animals
     b) **a form of indirect immunity of a given population that occurs when a significant proportion of members of that population has been immunized**
     c) immunity against one disease that occurs as a side effect of gaining immunity against another one
     d) the immunity that occurs when large groups of organisms are crowded in a limited space

SUPPLEMENTARY INFORMATION C

Multiple regression analysis of attitudes towards the COVID-19 vaccine

Predictor	Beta	B	Standard error	$t(457)$
Intercept		15.32	3.31	4.63***
Fear of COVID	.14	.27	.08	3.50***
Containment-related behavior	.04	.051	.06	.89
Perceived infectability	.02	.02	.04	.43
Germ aversion	-.05	-.06	.04	-1.31
Attitudes towards science	.27	.21	.04	7.44***
Conspiracist ideation	-.04	-.03	.04	-.84
COVID-19 hoax	-.38	-.76	.10	-7.31***
SARS-CoV-2 human made	-.12	-.276	.11	-2.53***
Knowledge about vaccines	-.01	-.06	.15	-.39

*** $p < .001$