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ORIGINAL ARTICLE

Covid-19 vaccination intentions and uptake pre- and post-vaccine availability: a cross-sectional comparison of theory of planned behavior, anticipated regret, and optimistic bias

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Abstract

Aim Vaccination hesitancy threatens herd immunity and reduces the chances of overcoming pandemics such as the recent Covid-19 pandemic. The present investigation looked at psychological predictors of Covid-19 vaccination intention and vaccination uptake.

Subject and methods Two representative Norwegian samples (collected in 2020, $N = 1003$, and 2022, $N = 1000$) filled in online questionnaires assessing variables of the theory of planned behavior (attitudes, social norms, and perceived behavioral control) as well as optimistic bias and anticipated regret.

Results Results showed that these variables could explain 69% of the variance in vaccination intentions and 41% of the variance in vaccination uptake. Significant predictors in both samples include attitudes, social norms within the family, perceived behavioral capability, and higher anticipated regret for *not* getting vaccinated. Intentions were also predicted by lower anticipated regret for getting vaccinated, and vaccination uptake was additionally predicted by older age and lower perceived behavioral autonomy. Optimistic bias did not predict intentions to get vaccinated or vaccination uptake.

Conclusion Interventions designed to increase vaccination uptake should focus on attitudes, norms, perceived behavioral control, anticipated regret, and possibly altruistic motivations.

Keywords Covid-19 vaccination intentions · Covid-19 vaccination uptake · Theory of planned behavior · Optimistic bias · Anticipated regret

Introduction

The WHO declared the outbreak of the Coronavirus a pandemic in March 2020. By September that year the number of deaths caused by the virus surpassed one million worldwide and is in June 2023 approaching seven million (WHO 2023a). The first vaccine was approved and administered in December 2020. By June 2023 no more than 66% of the population worldwide is vaccinated with a complete primary series, with numbers varying between 100% for some countries and below 10% for others (WHO 2023a). The success of overcoming the Covid-19 pandemic, as well as future pandemics, does not only depend on the effectiveness of available vaccines. A prerequisite of the success of any vaccine is the population's willingness to be immunized. High rates of vaccination hesitancy in the population may greatly reduce the chances of overcoming any pandemic (Sallam 2021).

Factors predictive of vaccination uptake identified by earlier research entail socioeconomic factors, including higher income and education (e.g., Jain et al. 2017), Caucasian ethnicity and health insurance (e.g., Fisher et al. 2013 for HPV-vaccination) and psychological factors, such as perceived risk, susceptibility, and severity (e.g., Brewer et al. 2007 for adult vaccination against infectious disease). A recent meta-analysis (Fajar et al. 2022) investigating global prevalence of Covid-19 vaccination hesitancy found hesitancy rates to be approximately 25%. Being female, below the age of 50, single, unemployed, living in households of

Data on vaccination intention pre-vaccine availability were published earlier. See Wolff (2021).

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five or more, having less education, not working in health care, and considering Covid-19 vaccines unsafe predicted vaccination hesitancy. Vaccination uptake was predicted by living with children, maintaining physical distancing norms, having ever tested for COVID-19, and having a history of influenza vaccination. Ebrahimi et al. (2021) reported that being male, rural residency, having underage children, and preferring unmonitored media platforms, but not educational background predicted vaccination hesitancy for Covid-19 in a large Norwegian sample.

The present study investigates psychological factors that may influence the decision to get vaccinated against Covid-19. The theory of planned behavior (TPB, Ajzen 1985, 1991), optimistic bias, and anticipated regret are examined as possible predictors of vaccination uptake in a representative Norwegian sample. This investigation is a follow up of earlier research by the same author (Wolff 2021). This allows for a comparison of predictors of vaccination intention measured the month before vaccination became available (December 2020), with predictors of vaccination status assessed the month after all restrictions were lifted in Norway (March 2022).

The theory of planned behavior (Ajzen 1985, 1991) is an expectancy-value model that has proven its utility in predicting a variety of behaviors in various contexts, including health behaviors. It has been used to predict intentions to obtain genetic testing (e.g., Wolff et al. 2011), actual vaccination uptake (e.g., Gerend and Shepherd 2012), and intentions to get vaccinated against Covid-19 (e.g., Sherman et al. 2020). The theory claims that intentions are the direct antecedent of any planned behavior. Behavioral intentions are in turn determined by attitudes, social norms, and perceived behavioral control. Attitudes are the individual's cognitive and affective evaluation of the behavior as either positive or negative. Social norms refer to the perceived social pressure to either perform or not to perform the behavior. Social norms include injunctive norms (how people *should* act) and descriptive norms (how people act). Perceived behavioral control is the individual's perceived self-efficacy. It consists of perceived capacity (the ability to perform the behavior) and perceived autonomy (the belief that the decision to perform the behavior lies within the individual's control).

Wolff (2021) found that the theory of planned behavior efficiently predicted vaccination intentions, with attitudes, social norms within one's family, and perceived capability being significant predictors. Several other studies have used the theory of planned behavior to predict Covid-19 vaccination intentions: Sherman et al. (2020) found that vaccination intention was predicted by positive attitudes, lower concerns for vaccination side effects, increased information sufficiency, increased perceived risk of Covid-19 for others (but not for oneself), older age, and influenza vaccine history in a British adult sample. Fan et al. (2021) found that, in addition to influenza vaccination history, attitudes but neither social norms nor perceived behavioral control predicted vaccination intentions in Chinese university students. Integrating the theory of planned behavior and the health belief model (Rosenstock 1966), Shmueli (2021) found that higher education, influenza vaccine history, perceived benefits and severity of infection, as well as subjective norms and perceived behavioral control predicted vaccination intentions in a representative Israeli sample. Servidio et al. (2022) found attitudes, subjective norms, and perceived behavioral control to predict both vaccination intentions and vaccination uptake in a sample of Italian cancer patients. Comparing the predictive power of theory of planned behavior, the health belief model, and five psychological antecedents (Betsch et al. 2018), Hossain et al. (2021) found the theory of planned behavior to be a better predictor of Covid-19 vaccination hesitancy than both the health belief model and psychological antecedents among adults in Bangladesh.

In addition to the theory of planned behavior, other variables have been suggested as possible predictors of vaccination intention and uptake, including optimistic bias and anticipated regret. Optimistic bias is the individual's tendency to overestimate the likelihood of experiencing positive outcomes (e.g., good health) while at the same time underestimating the likelihood of experiencing negative outcomes (e.g., illness), compared to others (Weinstein 1980, 1983, 1989). Some authors (Bond and Nolan 2011; Dubov and Phung 2015) have suggested that optimistically biased people may find it less necessary to get vaccinated. This would coincide with the fact that increased perceptions of vulnerability and risk regarding a disease have been shown to predict positive attitudes toward vaccination (Timmermans et al. 2008) and vaccination uptake (Weinstein et al. 2007). Pascual-Leone et al. (2021) present data from several studies which strongly suggest the existence of an optimistic bias for getting infected and seriously ill from Covid-19 in populations all over the world. They argue that optimism bias may lead people to disregard public health recommendations and urge policymakers to address unrealistic optimism in educational and vaccination acceptance campaigns.

Maftei and Petroi (2022) found a negative correlation between optimistic bias and perceived Covind-19 threat, but no relation with vaccination status in a Romanian convenience sample. In a similar vein, Wolff (2021) did not find optimistic bias to predict intentions to get vaccinated against Covid-19. Neither relative perceived susceptibility nor relative perceived seriousness of prognosis predicted vaccination intentions.

Regret theory (Bell 1982, 1985; Loomes and Sugden 1982, 1987) proposes that people anticipate the feelings they may experience in the future when the outcome of a decision becomes apparent. Anticipating negative feelings like regret that may result from unwanted outcomes of a

choice may lead decision makers to avoid alternatives that entail great potential for regret and choose options that reduce the probability of future regret. A meta-analysis (Brewer et al. 2016) found anticipated regret to affect various types of health behavior, including vaccination. The authors found that anticipated regret for getting vaccinated was generally lower than anticipated regret for *not* getting vaccinated. This aligns with the fact that regret anticipated for easily justifiable decisions is generally lower than regret anticipated for less justifiable decisions (Zeelenberg and Pieters 2007). Wolff (2021) found anticipate regret to be one of the strongest predictors of Covid- 19 vaccination intentions, in addition to attitudes.

In accordance with earlier research (Wolff 2021), the following hypotheses are being investigated in the present study: Being vaccinated against Covid-19 correlates positively with positive attitudes, with social norms favoring vaccination, and with higher perceived behavioral control. Optimistic bias (lower perceived susceptibility and lower perceived seriousness of prognosis compared to others) correlates negatively with being vaccinated. Higher anticipated regret for *not* being vaccinated, and lower anticipated regret for being vaccinated correlate positively with being vaccinated. In addition, the study will compare predictors of vaccination intention assessed the month before vaccination became available (December 2020), with predictors of vaccination uptake assessed the month after all restrictions were lifted in Norway (March 2022).

Materials and methods

Participants and procedures

Data were collected in the same manner as in 2020 (see Wolff 2021). The data collection started during the last week of March, the week after all Covid-19 restrictions were lifted in Norway, and lasted until the third week of April 2022. A link to an online survey was sent to a representative sample of the Norwegian population above the age of 18. The sample consisted of participants randomly drawn from a panel of 80,000 Norwegians, stratified by age, gender, and geographical region. NORSTAT (a commercial European data collector) administered the data collection. The collected data were not weighted for representativeness, and data collection stopped once a number of 1000 completed surveys was reached ($N = 1000$). The participants mean age was 52.33 (SD = 16.68) (range 18–86), and 51% were male ($N = 510$). The response rate was 23.4%, with a dropout rate of 5%. Answering the survey took about 5 min.

Measures

As far as possible the same survey items as in the 2020 data collection (see Wolff 2021) were used in the present study. However, since the data in 2020 were collected before a vaccine became available while the present data were gathered after 89% of the population were fully vaccinated, some items needed to be moderated, and in some cases, vaccinated and non-vaccinated participants answered slightly different questions. All items were constructed in line with previous research for the purpose of the present investigation. Items were presented in the same order as they are described below. TPB-measures were constructed in accordance with Ajzen (2006) instructions.

Vaccinations status The following items assessed vaccination status: *I am not vaccinated against Corona./I am vaccinated against Corona … with one dose; … two doses; … three doses.* Participants marked the correct option. The number of received vaccine doses (0–3) was used as a continuous variable of vaccination status. This was subsequently compared to behavioral intentions to get vaccinated in 2020.

Attitudes Seven-point semantic differentials, including cognitive and affective evaluations of vaccination were used to measure attitudes. *To get a vaccine against Corona is: bad–good; stupid–wise; dangerous–safe; useless–effective; unpleasant–pleasant; irresponsible–responsible; disturbing–reassuring.* Scores were averaged to constitute a measure of attitude ($\alpha = 0.94$).

Subjective norms Injunctive and descriptive subjective norms for friends and family were measured by four 7-point scales: *What do your friends (your closest family) think of you taking a Corona vaccine?* anchored by *very much against it* (1) and *very much for it* (7). *Most of my friends (my closest family) got a Corona vaccine themselves*, anchored by *not correct* (1) and *correct* (7). Items for friends ($r = 0.73$; $p < 0.001$; $\alpha = 0.84$) and for family ($r = 0.75$; $p < 0.001$; $\alpha = 0.85$) were averaged.

Perceived behavioral control Two 7-point scales assessed capacity and autonomy. *I am able to get the vaccine if I want to* (capacity). *It is up to me whether I get vaccinated or not* (autonomy). Both items were anchored by *not correct* (1) and *correct* (7). Capacity and autonomy were only moderately correlated ($r = 0.28$; $p < 0.001$). Contrary to the original plan, items were therefore kept separately in the subsequent analysis.

Optimistic bias In accordance with Weinstein (1980), two 7-point scales measuring perceived relative susceptibility and perceived relative probability of a serious prognosis for

the participant compared to a reference group were used. *Compared to other Norwegians your own age, what is the likelihood that you will be infected with Corona?* (relative susceptibility). *Compared to other Norwegians your own age, what is the likelihood that you would experience a serious course of a Corona infection?* (relative seriousness of prognosis). Both items were anchored by *much lower* (1) and *much higher* (7). Even though susceptibility and prognosis of COVID-19 are not known to correlate, items correlated moderately ($r = 0.37$; $p < 0.001$). Still, items were kept separate but were reversed to constitute measures of optimistic bias.

Anticipated regret This was assessed in accordance with Brewer et al. (2016). Different items for participants who were vaccinated (i.e., they had earlier stated that they had received at least one dose) and for those who were not vaccinated were used. Vaccinated participants scored the following items on 7-point scales: (1) *I might come to regret taking the Corona vaccine.* (2) *If I had not gotten the Corona vaccine, I might have come to regret it.* Unvaccinated participants scored the following 7-point scales: (1) *If I do NOT get a Corona vaccine, I might regret it.* (2) *If I get the Corona vaccine, I might regret it*. All items were anchored by *very improbable* (1) and *very probable* (7). The score on *regret getting vaccinated* was subtracted from *not getting vaccinated* for all participants in order to construct a measure of net-anticipated regret (vaccinated: $r = -0.35$; unvaccinated: $r = -0.79$; $p < 0.001$).

Analysis plan

Analyses were run in IBM SPSS (version 25). A two-step hierarchical regression analysis was performed to test which variables correlated with vaccination status. In the first step (model 1) demographic variables and theory-of-planned-behavior variables were entered. In the second step (model 2) perceived relative susceptibility and seriousness, as well as anticipated regret for getting vaccinated and for *not* getting vaccinated were entered. This order was chosen to investigate whether entering additional variables could improve the predictive power of the TPB. A separate regression analysis was run keeping only significant predictors, and replacing anticipated regret for getting vaccinated and for *not* getting vaccinated by the compound measure of net-regret (model 3).

Results

Most participants in the present investigation were fully vaccinated, i.e., 95.6% had received at least two doses of Covid-19 vaccine. Only 3.3% of the present sample were unvaccinated, and 1.1% had received only one dose. See Table 1 for vaccination status for various age groups and for men and women. Numbers are similar to the ones observed in the population at the time of data collection, where 91% had received at least two doses of a vaccine (FHI 2022). However, the rate of vaccination in the present sample is a lot higher than would have been expected from the intentions stated in the 2020 sample, where 61.6% of respondents intended to get vaccinated, 13.8% intended not to get vaccinated, and 24.8% were uncertain (see Wolff 2021).

Table 1 Number of vaccinated and not vaccinated participants in various age groups and among men and women

Age	18–29 ($n = 125$)	30–39 ($n = 118$)	40–49 ($n = 163$)	50–59 ($n = 238$)	60–69 ($n = 182$)	70–79 ($n = 147$)	= < 80 ($n = 27$)	Total ($N = 1000$)
Not vaccinated								
	9	6	6	4	7	1	0	33
Vaccinated with…								
one dose	6	2	0	1	2	0	0	11
two doses	40	31	26	23	12	5	1	138
three doses	70	79	131	210	161	141	26	818
Gender	Men ($n = 510$)		Women($n = 490$)					
Not vaccinated	20		13					
Vaccinated with…								
one dose	7		4					
two doses	68		70					
three doses	415		403					

Table 2 Means, standard deviation, and Pearson correlation matrix for all variables (scale from 1 to 4 for being vaccinated; 1 to 7 for other variables)

	M	SD	1	2	3	4	5	6	7	8	9	10	11
1 Being vaccinated	3.74	.64											
2 Age	52.33	16.68	.26**										
3 Female gender	–	–	.03	–.17**									
4 Attitude	6.06	1.15	.60**	.27**	–.02								
5 Social norm Friends	6.52	.89	.49**	.13**	.05	.72**							
6 Social norm Family	6.58	.97	.50**	.12**	.05	.63**	.70**						
7 Perceived control (capability)	6.76	.84	.35**	.09**	.04	.45**	.47**	.44**					
8 Perceived control (autonomy)	6.46	1.27	.03	.00	–.00	.16**	.15**	.12**	.26**				
9 Relative susceptibility	4.11	1.24	–.07*	.09**	–.09**	–.04	–.02	–.03	–.05	.02			
10 Relative seriousness	3.66	1.49	–.14**	–.16**	–.03	–.09**	–.07*	–.08**	–.01	.03	.27**		
11 Anticipated regret vaccination	2.12	1.59	–.38**	–.19**	.06	–.65**	–.47**	–.37**	–.29**	.11**	–.10*	–.04	
12 Anticipated regret no vaccination	5.98	1.57	.48**	.20**	.04	.70**	.53**	.48**	.31**	–.08*	–.05	.14**	–.47**

*$p < .05$ **$p < .01$

Table 3 Two-step hierarchical regression analysis (models 1 and 2) and separate regression containing significant correlations only (model 3) with behavioral intention to get vaccinated (2020) and with being vaccinated (2022)

	B		95% CI		SEB				R^2		ΔR^2	
	2020[1]	2022	2020[1]	2022	2020[1]	2022	2020[1]	2022	2020[1]	2022	2020[1]	2022
Model 1									.66**	.40**	.66*	.40**
Age	.01	.01	[.00 .01]	[.00 .01]	.00	.00	.05*	.13**				
Female gender	–.10	.06	[–.24 .05]	[.00 .13]	.07	.03	–.03	.05				
Attitude	.66	.23	[.57 .74]	[.19 .27]	.04	.02	.43**	.41**				
Social norm Friends	.18	.01	[.09 .27]	[–.04 .07]	.05	.03	.13**	.02				
Social norm Family	.33	.12	[.24 .42]	[.08 .17]	.05	.02	.25**	.19**				
Perceived control (capability)	.14	.07	[.09 .19]	[.02 .11]	.03	.02	.12**	.07*				
Perceived control (autonomy)	–.06	–.04	[–.11 –.01]	[–.07 –.02]	.03	.01	–.04	–.08*				
Model 2									.70**	.41**	.05**	.01*
Age	.00	.01	[–.00 .01]	[.00 .01]	.00	.00	.02	.12**				
Female gender	–.13	.05	[–.27 .01]	[–.01 .11]	.07	.03	–.03	.04				
Attitude	.47	.19	[.38 .55]	[.14 .24]	.04	.03	.30**	.33**				
Social norm Friends	.11	.01	[.03 .20]	[–.05 .06]	.04	.03	.08	.01				
Social norm Family	.23	.12	[.15 .32]	[.07 .16]	.04	.02	.17**	.18**				
Perceived control (capability)	.09	.07	[.04 .14]	[.02 .11]	.03	.02	.08**	.09*				
Perceived control (autonomy)	–.03	–.04	[–.08 .02]	[–.06 –.01]	.03	.01	–.02	–.08*				
Relative susceptibility	–.06	–.02	[–.00 .12]	[–.01 .04]	.03	.01	–.04	–.03				
Relative seriousness	–.03	–.02	[–.02 .09]	[–.00 .04]	.03	.01	–.03	–.05				
Anticipated regret vaccination	–.16	–.01	[–.22 –.11]	[–.03 .02]	.03	.01	–.14**	–.02				
Anticipated regret no vaccination	.26	.04	[.20 .32]	[.02 .07]	.03	.01	.22**	.11*				
Model 3									.69**	.41**	.69**	.41**
Age		.01		[.00 .01]		.00		.12**				
Attitude	.48	.19	[.40 .57]	[.14 .24]	.04	.03	.31**	.34**				
Social norm Family	.31	.13	[.24 .38]	[.09 .17]	.04	.02	.23**	.19**				
Perceived control (capability)	.11	.07	[.06 .16]	[.03 .11]	.03	.02	.09**	.09*				
Perceived control (autonomy)		–.04		[–.07 –.02]		.01		–.08*				
Net anticipated regret (no vaccination – vaccination)	.22	.02	[.18 .25]	[.01 .04]	.02	.01	.32**	.10*				

*$p < .01$, **$p < .001$, [1]2020 data are published earlier, see Wolff, 2021

Table 2 displays means, standard deviations, and correlations for all variables in the current study. Table 3 displays the results of the regression analyses for data collected in 2020 (see Wolff 2021) and the present data collection (2022). The first model shows the correlations of demographic and theory-of-planned-behavior variables with vaccination intention (2020) and vaccination uptake (2022). Older age, positive attitudes, positive norms within one's family, and perceived behavioral control (both perceived capability and perceived autonomy) correlated with being vaccinated. These variables explained 40% of the variance. Attitudes and social norms displayed the strongest correlations. Interestingly, perceived behavioral autonomy correlated negatively with being vaccinated.

In the second step, additional variables were entered into the model. This slightly increased the explained variance to 41%. Perceived relative susceptibility and seriousness did not correlate with vaccination status. Neither did anticipated regret for being vaccinated. However, anticipated regret for *not* being vaccinated correlated positively with vaccination uptake.

Model 3 kept only significant predictors in the analysis and replaced measures of anticipated regret for being vaccinated and for *not* being vaccinated by the compound measure of net anticipated regret. Findings showed that attitudes, social norms within the family, age, net-anticipated regret, and both measures of perceived behavioral control (capability and autonomy) could explain 41% of the variance in vaccination status. (Retaining only the measure of anticipated regret for *not* being vaccinated in the analysis yields parallel results. To allow for a comparison with the 2020 results, net-anticipated regret was included.)

Comparing 2020 to 2022 data showed that the variance explained in intention (2020) is 69%, while the variance explained in vaccination uptake (2022) is 41%. Significant predictors of intention and vaccination are quite similar though. Both are predicted by attitudes, social norms within the family, perceived behavioral capability, and anticipated regret for *not* being vaccinated. Anticipated regret for getting vaccinated predicted intentions but not vaccination. Vaccination on the other hand was additionally predicted by older age and lack of perceived behavioral autonomy.

Discussion

Findings show that the sample at hand is similar to the population in Norway regarding Covid-19 vaccination status, in that 95.6% of participants and 91% of the general population above the age of 18 are fully vaccinated (FHI 2022). These rates are among the best in the world (WHO 2023a). They are also higher than findings reported in a meta-analysis by Brewer et al. (2007) who found vaccination uptake for infectious diseases to vary between 6 and 86% (with a median uptake of 51%). The rate of vaccination both in the sample and in the Norwegian population also exceeds the 61% of participants who in 2020 stated the intent to get vaccinated once a vaccine became available (Wolff 2021).

The variance explained in intentions assessed in 2020 (Wolff 2021) was higher than the variance explained in vaccination status in the present investigation, 69 and 41%, respectively. This is in line with previous research showing that the theory of planned behavior predicts behavioral intentions better than behavior (Armitage and Conner 2001; Rich et al. 2015). This is to be expected as the theory of planned behavior proposes that predictor variables, i.e., attitudes, norms, and perceived control, are the immediate precursors of intentions which in turn predict behavior.

The predictors of vaccination intent (2020) and of vaccination uptake (2022) are very similar. Both are predicted by positive attitudes toward vaccination, favorable social norms within one's family, perceived capability (one measure of perceived behavioral control), and high anticipated regret for *not* getting vaccinated. Vaccination intent (2020) was additionally predicted by low anticipated regret for getting vaccinated, and vaccination uptake (2022) was also predicted by older age (which is a risk factor for a serious prognosis), and somewhat surprisingly by lack of perceived autonomy (another measure of perceived behavioral control).

These findings are also similar to previous research that has used the theory of planned behavior to predict Covid-19 vaccination intentions and found the following predictors: age, positive attitudes, and increased perceived risk for others (Sherman et al. 2020); attitudes, but neither social norms nor perceived behavioral control (Fan et al. 2021), perceived severity, subjective norms and perceived behavioral control (Shmueli 2021); and attitudes, social norms, and perceived behavioral control (Servidio et al. 2022).

The fact that perceived autonomy correlates negatively with being vaccinated is contradictory to the theory of planned behavior which claims that perceived behavioral control, including perceived autonomy, correlates positively with behavioral intentions and behavior (Ajzen 1985, 1991). In hindsight, however, it seems plausible that respondents who disagree with the statement *It is up to me whether I get vaccinated or not* might be the ones who feel obligated to get vaccinated. Such an obligation may be caused by a feeling of responsibility for protecting others, or from the fact that certain restrictions applied to people who were not vaccinated. Still, Norway had hardly any differential restrictions for vaccinated and unvaccinated citizens, only some differences in quarantine length and travel restrictions (Government.no 2023). This supports the fact that a perceived obligation may stem from altruistic motives.

Optimistic bias, assessed as lower perceived susceptibility and less serious prognosis compared to others, did neither

predict intention to vaccinate nor vaccination uptake. These findings contradict other research showing that increased perceived risk and vulnerability predict protective heath behaviors, including vaccination (Brewer et al. 2007). However, the results are in line with Sherman et al. (2020) who found that participants were more willing to vaccinate against COVID-19 when they perceived greater risk for others but not for themselves. Results also fit with the finding discussed above, that people may feel obligated to vaccinate against Covid-19 to protect others. As discussed by Wolff (2021), Covid-19 may not pose a serious risk for most participants and vaccination may therefore be motivated by protecting others rather than oneself. This altruistic motivation may also contribute to vaccination uptake for other diseases. It has for example been shown that appealing to altruistic motives, i.e., the protection of sex partners, may increase men's willingness to vaccinate against HPV (Bonafide and Vanable 2015). For diseases where the main motivation of vaccination is self-protection, increased perceived personal risk and vulnerability are likely to be predictors of vaccination uptake (Brewer et al. 2007). Optimistic bias might still influence vaccination uptake for those diseases even though it did not influence vaccination intention and uptake in the present study.

Anticipated regret for *not* getting vaccinated correlated with vaccination uptake in the present investigation. This is in line with Wolff (2021) who found that Covid-19 vaccination intentions were predicted by high anticipated regret for *not* getting vaccinated and low anticipated regret for vaccination. Findings also correspond with Brewer et al. 2016 who found that anticipated regret was lower for vaccination than for non-vaccination, and with Zeelenberg & Pieters (2007) who showed easily justifiable choices (virtues, health promotion) to be associated with less anticipated regret than choices that are hard to justify (vices, risk behaviors).

As in Wolff (2021), it is interesting to note a negative correlation of anticipated regret for getting vaccinated and for *not* getting vaccinated. As anticipated regret is determined by the probability of negative outcomes of an alternative, this finding is somewhat paradoxical. This is because the more negative the consequences of not being vaccinated are, the more willing one should be to accept negative consequences (i.e., side effects) of a vaccine. This would imply a positive correlation of anticipated regret for getting vaccinated and for not getting vaccinated. See Wolff (2021) for a discussion of possible explanations.

The present investigation has several limitations. First and foremost, it did not actually predict vaccination behavior but rather post-dicted it. All measures were obtained after most participants were vaccinated. It is therefore not possible to conclude whether attitudes influenced vaccination behavior or whether getting vaccinated leads people to form positive attitudes toward vaccination. Possibly, both processes are at work. The current approach also implies that participants had to assess the potential of regret for different alternatives after they had made an irreversible choice (at least the vaccinated ones). This may lead participants to exaggerate the difference in anticipated regret between chosen and not chosen alternative. All of this could of course have been circumvented with a longitudinal design following the same participants over time, which would have been preferable. It is still interesting to observe that participants report not regretting their choice. Also, the observed relations between the predictor variables and vaccination status are very similar to the ones observed in the data obtained before vaccination became available.

Also perceived susceptibility and seriousness of prognosis were measured in relative terms, i.e., compared to others. It is therefore not possible to conclude whether susceptibility and seriousness of the prognosis are perceived to be high or low in absolute terms. This way of assessment was chosen to construct a measure of optimistic bias.

Furthermore, several constructs have been assessed with single-item measures. This holds true for perceived capability and autonomy, relative susceptibility and seriousness of prognosis, and anticipated regret for getting vaccinated and for *not* getting vaccinated. However, for simple constructs, single-item measures may outperform multi-item measures (Bergkvist and Rossiter 2007).

Another limitation of this research concerns the operationalization of vaccination status as a continuous variable (from zero to three doses of vaccine), since it could be argued that vaccination status is a dichotomous variable (one either is or is not vaccinated). This was done for two reasons: to overcome statistical problems that arise from a very low number of participants with zero vaccination doses, and to allow for a direct comparison to the data collected in 2020. It seems reasonable to assume that participants with fewer doses are more skeptical toward vaccination, as vaccines had been fully available for all for at least 6 months by the time of data collection. The similarity of the results from 2020 and 2022 also underline that the conceptualization of vaccination status as a continuous variable is not nonsensical.

In conclusion, results support the use of the theory of planned behavior (Ajzen 1985, 1991) as a theoretical model to predict vaccination intentions and vaccination uptake for Covid-19. The theory explains 70% of the variance in intentions and 41% of the variance in vaccination uptake and all proposed predictor variables (attitudes, norms, and perceived control) turned out to be significant. However, the model's predictive power was further increased by including measures of anticipated regret.

Interventions designed to increase vaccination uptake should focus on the variables found to correlate with intentions and vaccination uptake. These were positive attitudes,

favorable subjective norms within one's family, perceived capability, and anticipated regret for *not* getting vaccinated. Interventions could focus on increasing positive attitudes through informing about vaccination benefits; however, it might be equally effective to focus on the disadvantages and possible negative consequences of *not* being vaccinated to increase non-vaccination regret.

Focusing on the risk of Covid-19 for others, rather than individual risk might be another way to increase vaccination uptake. This is supported by the finding that relative perceived susceptibility and seriousness of prognosis (i.e., optimistic bias) did not correlate with vaccination intentions and uptake. This may be because Covid-19 does not pose a grave risk for most of the population, at least not in Norway (FHI 2020). However, optimistic bias might still influence vaccination uptake for diseases that are riskier for most individuals.

Another finding supporting focusing on the risk or others is that vaccinated participants reported less autonomy over the decision than unvaccinated participants. This may indicate that vaccinated participants might have felt obligated to get vaccinated, possibly to protect others. Appealing to altruistic norms and the obligation to protect others, for example older family members, may therefore be one way to increase vaccination rates. This approach is also supported by the fact that norms within the family seem to influence vaccination uptake.

Finally, while this research focused on vaccination uptake for Covid-19, hopefully some directions for future research and some generalizable finding may be gained from it. Those may include the following: The theory of planned behavior is a useful model for explaining vaccination behavior, but its predictive power may be increased by including measures of anticipated regret (also see Sandberg and Conner 2008). Future research should look at whether vaccination uptake for diseases that are not threatening for many individuals can be increased by focusing on the risk for others and altruistic norms, rather than individual risk.

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Data Availability The data that support the findings of this study are available from the corresponding author, upon reasonable request.

Declarations

Ethics statement Despite being on human participants the present study does not require ethics approval according to local legislation and institutional requirements. Ethical review boards will therefore not evaluate it. The author still judged the research to be within the requirements of the Helsinki declaration (World Medical Association 2013). The following information was given to participants: the studies subject was Corona vaccination; participation implied consent, was voluntary and could be stopped at any moment; data collection was anonymous.

Conflict of interest The author declares no conflicts of interest.

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