

## RESEARCH ARTICLE

# Contribution of rationality to vaccine attitudes: Testing two hypotheses

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**Abstract**

Although previous studies have demonstrated an association between vaccine attitudes and cognitive biases, often resulting in vaccination hesitancy, the exact contribution of rationality has not been fully clarified. We tested two hypotheses regarding the impact of rationality on vaccine attitudes stemming from bounded and expressive rationality. We focused on parental vaccine attitudes operationalized by the affective, behavioral, and cognitive attitude components and investigated how these are influenced by disillusionment toward authorities and ability to engage in rational thinking operationalized using cognitive reflection and heuristics and biases tasks. The study was of a cross-sectional correlational design with a non-probabilistic sample of 823 volunteer participants surveyed online in April and May 2018 in Croatia. The results identified disillusionment toward authorities as a predictor of all components. Furthermore, performance on heuristics and biases tasks also predicted the affective and cognitive, but not the behavioral component, whereas cognitive reflection had no impact on vaccine attitudes. Next, a moderation effect of disillusionment toward authorities on the association between the omission bias task and all attitude components was identified. Parents with low disillusionment demonstrated positive vaccine attitudes regardless of their rationality, whereas for parents with high disillusionment a significant positive correlation between performance on the omission bias task as assessed with a vaccination vignette and attitudes was identified. This suggests that the ability to resist vaccine specific omission bias, that is, higher rationality, can decrease the negative effects of disillusionment, which supports the bounded rationality hypothesis.

**KEYWORDS**

bounded rationality, cognitive reflection, expressive rationality, heuristic thinking, vaccine attitudes

## 1 | INTRODUCTION

Despite ever growing evidence that vaccines are safe and effective, distrust toward vaccines is continuously present and undermines vaccination rates (Caron-Poulin et al., 2017; GAVI, 2012; WHO, 2012); making vaccine hesitancy one of the top 10 global health threats (WHO, 2019). Among the main reasons for such under-vaccination are parental vaccine attitudes, as different studies have demonstrated

an important role of the human factor and individuals' acceptance of doctors' advice in vaccine complacency and disease transmission. In explaining the underlying cause, Oraby and Bauch (2015) argue that vaccine acceptance behavior is strongly associated with individuals' cognitive processes and biases, showing that factors such as framing, subjective probability and risk perception impact this behavior. Jacobson et al. (2007) furthermore identified factors underlying such cognitive biases in parents who do not vaccinate their children.

Specifically, these are related to a desire to find order and predictability in random data, difficulty in detecting and correcting errors in reasoning with incomplete and unrepresentative data, eagerness to interpret ambiguous data to fit expectations, as well as self-serving distortions of reality, errors in second-hand information and exaggerated impressions of social support. For example, the lack of direct experience with an infectious disease can lead to the incorrect assumption that such a disease is no longer a threat and that therefore vaccination is unnecessary—which is found to be a common belief among parents with negative vaccine attitudes (Jacobson et al., 2007). Similarly, a study by Asch et al. (1994) showed the tendency toward omission bias to predict negative vaccine attitudes as strongly as beliefs about vaccine harmfulness. In this study, most parents reported they would feel guiltier if their child died from vaccine complications than from the disease itself, even when knowing that the odds of catching the disease are more likely. In the same study, participants who believed vaccines to be beneficial but still showed negative attitudes were more likely to show omission bias in their reasoning. A more recent study replicated these findings, indicating proneness to omission bias was associated with avoiding the flu vaccine (Dibonaventura & Chapman, 2008). Moreover, it has been shown that parents with negative vaccine attitudes place their trust in the media and other non-official sources of information which present facts in a way that appeals to individuals' emotional, but not rational, processing channels, that is, in an overly personalized, emotional and vivid fashion (Ubel et al., 2001; Wolfe et al., 2002).

Although these studies have demonstrated an association between vaccine attitudes and cognitive biases, often resulting in vaccination hesitancy, the exact contribution of rationality to vaccine attitudes has not been fully clarified. Several theoretical perspectives approach the issue of human rationality and explain why individuals' responses on different reasoning tasks often differ from those considered normative, thereby displaying information processing biases (Stanovich & West, 2000). In this study, we focused on the bounded and expressive rationality approach to explore the contribution of rationality on parental attitudes toward children vaccination. The bounded rationality approach recognizes that cognitive biases have great internal consistency (Stanovich & West, 2000) and states that, due to inherent cognitive and computational limits, individuals err on their performance on such tasks in systematic and predictable ways (Stanovich & West, 2000). On the other hand, the expressive rationality theory emphasizes that individuals' style of reasoning serves an important additional purpose, that is, that in situations which regard culturally disputed issues, people rationally engage with information that conforms to their beliefs (Kahan, 2017). Such deviations from normative models of rationality have been demonstrated in various types of attitudes, such as political issues and risks of climate change (Kahan, 2017; Kahan et al., 2012), as well as, in recent years, health attitudes (Blumenthal-Barby & Krieger, 2015; Gigerenzer & Gray, 2011).

In the specific context of vaccination, the bounded and expressive rationality theories give different predictions on the association of rationality and vaccine attitudes. First, related to the bounded

rationality approach (Kahneman, 2011), it would be possible to suggest that a more pronounced general tendency toward rational thinking and higher cognitive abilities would be associated with more positive vaccine attitudes, that is, higher acceptance of vaccinating children. Second, the expressive rationality theory suggests a more complex effect of rationality and cognitive abilities on attitudes. Hereby, rationality does not impact the directionality of individuals' original attitude, as these are formed based on their other values and beliefs. Thus, individuals higher in rationality would be able to better justify these attitudes once they were formed, resulting in stronger and more polarized views (Kahan, 2017; Kahan et al., 2012). In other words, individuals that are more rational would utilize their distinctive cognitive proficiencies to recognize situations relevant for attitude formation and interpret the vaccine data in a way that allows them to form stronger arguments in ways that are congruent with their formed identity, either pro or con vaccination. Thus, it would be of relevance to identify the identity-forming factor relevant for the initial formation of attitudes; in the case of vaccination, this could be related to disillusionment toward authorities. Namely, a systematic review of factors underlying parental decisions about childhood vaccinations found an association between lower vaccine uptake and lower trust in the healthcare system and/or government, revealing that vaccine-avoiding parents feel dissatisfied with their health professional consultations (Brown et al., 2010). Therefore, in line with the expressive rationality view, disillusionment toward authorities could represent an identity-forming factor for the formation of vaccination attitudes, suggesting that more rational individuals who trust authorities would be prone to becoming more pro-vaccine oriented, whereas more rational individuals with a higher disillusionment toward authorities would likely develop even stronger negative vaccine attitudes.

Building on previous findings, in the present study we addressed vaccine attitudes with the aim of investigating their relationship with individuals' rationality, namely testing two opposing predictions on this association stemming from bounded and expressive rationality. Attitudes are generally defined as a specific response, or general evaluation, to an antecedent stimulus or attitude object (Breckler, 1984). The attitude object may or may not be observable, whereas, according to tripartite attitude models, attitudes are typically expressed in three components—the affective, behavioral and cognitive component (ABC; Breckler, 1984). The affective component is reflected in the sympathetic nervous response as well as verbal statements of affect; the cognitive component refers to perceptual responses and verbal statements of beliefs; and the behavioral component includes overt actions and verbal states of behavior. In the context of vaccine attitudes, these are manifested in parental affective responses toward vaccinating, their beliefs regarding vaccines, and their behavior—whether they do or do not vaccinate their children. In this study, we addressed all these vaccine attitude components within the tripartite attitude model.

In addressing our aim, we operationalized rationality with two different rational thinking indicators: first, as cognitive reflexivity, that is, the proneness or ability to overcome an incorrect intuitive answer and engage in further reflection to find a correct answer (Toplak et al., 2011), and second, as the ability to solve objective tasks

that trigger heuristic and biased thinking (Toplak et al., 2011). In assessing these skills, we focused on parental proneness toward omission bias, causal base rate and outcome bias. Among these, the omission bias represents a tendency to judge actions that produce bad outcomes as worse than equally or more harmful outcomes of inactions (Asch et al., 1994), so we expected parents with more negative vaccine attitudes to be more prone to this bias. The causal base rate bias indicates a tendency to rely on salient personal testimonies in spite of large-sample information going in the other direction (Fong et al., 1986). Similar to that, the outcome bias occurs in situations where the same behavior produces more ethical condemnation when associated with bad than good outcomes, even if the outcome is determined by chance (Toplak et al., 2011). We expected this bias to be associated with negative attitudes, as vaccine avoiding parents are shown to be focused on side-effects of vaccines (Brown et al., 2010). Based on previous reports indicating how vaccine critical media often use case-based information (Betsch et al., 2010), it is possible to suggest that this bias may also predict negative attitudes. We expected all three attitude-components to be associated with rationality. Regarding this operationalization, we specifically hypothesized two possible associations, which would support the bounded rationality approach. First, a linear association between rationality and vaccine attitudes, meaning that individuals who are more rational would have more positive attitudes toward vaccination, since their beliefs and behaviors are closer to the normative ideal. Alternatively, an interaction between rationality and vaccine attitudes, in a way that a positive association between rationality and attitudes is stronger for parents high in disillusionment than those low in disillusionment. Finally, we hypothesized one possible association, which would support the expressive rationality approach. According to this hypothesis, the association of rationality and positive vaccine attitudes would be negative for parents high in disillusionment and positive or none for parents low in disillusionment.

## 2 | METHODS

### 2.1 | Design

The study was correlational, of a cross-sectional design. Data were collected via online survey platforms, from April 2018 to May 2018 in Croatia. The survey was posted online and shared via social media—the Croatian parents' info portal Roda (<http://www.roda.hr/>) and Facebook and was based on a non-probabilistic study sample of volunteer participants. The study did not receive any particular funding. Approval was obtained from the Ethics committee of School of Medicine, University of Split, Croatia according to their Code of biomedical research.

### 2.2 | Participants

Participants were recruited online. They were told the purpose of this study and, before entering it, asked to give informed consent after

which they continued to the online questionnaire. The completion of the prepared instruments lasted 15–20 min. All the instruments were presented in the Croatian language and instruments for which there was no Croatian version available were translated using the back-translation method (Trust Towards Authorities–Disillusionment Scale, TTA-D, VHS). Out of 890 participants who completed the survey, we excluded those who do not have any children ( $N = 67$ ) and proceeded with the analyses on a total of 823 participants who have one or more children (94% female, average age  $M = 33$  years,  $Sd = 6.4$ ).

### 2.3 | Instruments

The participants first completed the General Information Survey which included demographic information (age, gender, education, profession, marital status, and number of children) and a question regarding vaccination behavior which assessed their real-life vaccination choices. In this question participants were asked to indicate whether they fully vaccinated, partially vaccinated or did not vaccinate their children at all (the question *If you have children, have they been vaccinated so far?* was answered in the following scale: (a) they received all mandatory vaccinations, (b) they received some but not all mandatory vaccinations, (c) they received none of the mandatory vaccinations, and (d) I have no children). Later on, this question served as the third criterion variable in our analyses, namely as the behavioral component of vaccine attitudes. Next, they completed several standardized instruments which included the Cognitive Reflection Test (CRT) (Toplak et al., 2011), Heuristics and Biases Tasks (Toplak et al., 2011), TTA-D Scale (Jolley & Douglas, 2014a), Affect Toward Vaccination (ATV) scale which was designed for the purpose of this study to represent the first criterion, the affective component of vaccine attitudes and, finally, the Vaccine Hesitancy Scale (VHS) (Shapiro et al., 2018) which we used to represent the second criterion, the cognitive component of vaccine attitudes.

The CRT (Frederick, 2005) is a three-item instrument designed to assess individuals' ability to resist giving intuitive but incorrect answers which the respondents reach if they do not consider the question carefully. In this study, we added three more items, are presented in the supporting information Table S1, which were chosen from additional, previously published CRT items because they were generally easier than the original items, since the original three items proved (Primi et al., 2016; Thomson & Oppenheimer, 2016; Toplak et al., 2014). Thus, our final CRT instrument had six items in total (e.g., *A bat and a ball cost \$1.10 in total. The bat costs \$1.00 more than the ball. How much does the ball cost? \_\_\_\_\_ cents*). The accuracy of each question was objectively scored and the number of correctly answered questions added. A higher score on this scale indicates a greater degree of cognitive reflection. Reliability estimated using the Cronbach  $\alpha$  coefficient of this scale was .75 in this study.

The Heuristics and Biases Tasks included omission bias, causal base rate and outcome bias. In the omission bias task (Asch et al., 1994) the participants have to imagine a hypothetical situation and decide if they would vaccinate their child based on the odds of

potential side effects of the vaccine and disease outcome. The causal base rate (Fong et al., 1986) is a task in which the participants have to choose which of two cars they would buy, depending on reviews from either a salient personal contact or a much larger group of anonymous car owners. Finally, in the outcome bias problem (Baron & Hershey, 1988) the participants judge the appropriateness of a doctor's decision on performing a surgery based on the surgery's outcome (patient's death vs. survival). Correct answers were objectively scored in all the tasks, and summed in a single measure, with a higher score indicating lower proneness to heuristic thinking, or higher proneness to rational thinking.

The TTA-D (Jolley & Douglas, 2014a) is a standardized six-item measure of disillusionment toward authorities involved in vaccination (e.g., *I feel tricked, cheated or deceived by those who are involved in immunizations [e.g., the government, pharmaceutical companies, etc.]*). Respondents rated each item on a 6-point scale (1—strongly disagree to 6—strongly agree). A higher score indicates higher trust, that is, lower disillusionment toward authorities. Reliability estimated using the Cronbach  $\alpha$  coefficient of this scale was .92 in this study.

The ATV was designed for the purpose of this study and included a range of both negative and positive emotional states (anger, fear, relaxation, disgust, anxiety, repulsiveness, and worry, calmness). The participants were asked to rate on a five-point scale how strongly they feel each of the listed emotions when thinking about vaccinating their child (1—very little to 5—very much). All positive emotions were reversely scored, and a sum score was computed such that higher values represented more negative affect toward vaccination. Reliability estimated using the Cronbach  $\alpha$  coefficient of this scale was .92. The scale is available in the supporting information, Appendix S1.

The VHS (Shapiro et al., 2018) represents a nine-item measure of hesitancy toward child vaccination (e.g., *New vaccines carry more risks than older vaccines*). Respondents rated each item on a five-point scale (1—strongly disagree to 5—strongly agree). A higher score indicates higher vaccination hesitancy. Reliability estimated using the Cronbach  $\alpha$  coefficient of this scale was .94 in this study.

Descriptive information on all the instruments is presented in Table 1.

## 2.4 | Statistical analysis

The data analysis was conducted using Statistica (TIBCO) and the Bayesian analyses were done using JASP (JASP Team, 2020).

The results were analyzed using descriptive, correlation, and hierarchical regression analyses. As the main reason for conducting hierarchical regression analyses was to investigate the interaction effects of rationality and disillusionment on vaccine attitudes, we decided to conduct the Bayesian model averaging (BMA) analysis (Bergh et al., 2021; Hinne et al., 2020). BMA recognizes that, although the amount of variance explained in the outcome will always be the greatest when all the predictors are included in the model (in this case the model with an interaction term), this type of model will nevertheless overfit the data and generalize poorly to other datasets (van den Bergh et al., 2021). Therefore, BMA tries to recognize the most appropriate model given the data. It does so by calculating the probability of each candidate model given the data and comparing that probability with a model's prior probability. In this case, we set uniform priors for all our models: As we are agnostic about the most appropriate models for our outcomes, we gave the all the same prior probability. By averaging these comparisons, BMA can inform us about the odds of each candidate model compared to all possible models averaged and these odds are expressed in the model Bayes factor (BFm). In this sense, the Bayes factor (BF) is the strength of evidence in favor of that model given the data compared to the averaged model. Models' Bayes factors can then be mutually compared to make conclusions about their relative performance, that is, it would be possible to quantify how much more or less the data favors model with an interaction term included over a model without an interaction. BFs ranging from 1 to 3 are often interpreted as anecdotal or insufficient evidence, BFs from 3 to 10 as moderate evidence, BFs from 10 to 30 as strong evidence, BFs from 30 to 100 as very strong evidence and BFs greater than 100 as extremely strong evidence.

## 3 | RESULTS

A correlation analysis was conducted as the first step in exploring the relationship between criterion (affective, cognitive, and behavioral components of vaccine attitudes) and predictor variables (cognitive reflection—CRT, heuristic thinking, disillusionment toward authorities—TTA-D). The obtained results indicated the expected strong positive correlations among the three criterion variables. All criteria were also negatively correlated with trust toward authorities and the ability to override heuristic thinking. Furthermore, the affective and cognitive components of vaccination attitudes were negatively correlated with cognitive reflection. Apart from being

Measure	M	Sd	Min	Max
Affect Toward Vaccination—ATV	21.01	8.54	8	40
Vaccine Hesitancy Scale—VHS	23.69	10.55	9	45
Cognitive Reflection Test—CRT	3.71	1.81	0	6
Heuristic thinking	1.43	0.91	0	3
Trust Towards Authorities—Disillusionment—TTA-D	18.14	8.75	6	36

**TABLE 1** Descriptive statistics of the administered instruments

Note: M—mean; Sd—standard deviation; Min—minimum; Max—Maximum.

statistically significant, these correlations differed in their magnitude. The greatest correlation was found between attitude components and disillusionment toward authorities, followed by heuristic and biases tasks, and cognitive reflection as quite small. Lower disillusionment toward authorities (TTA-D) was also correlated with cognitive reflection (CRT) and the ability to override heuristic thinking. The correlations are presented in Table 2.

Next, several hierarchical regression analyses were performed to test the two opposing hypotheses regarding the impact of rational thinking on three components of vaccine attitudes. To assess the effects of two different rational thinking indicators on vaccine attitudes, we conducted several regression analyses. The first regression analysis included disillusionment toward authorities (TTA-D) with cognitive reflection (CRT) as the first measure of rational thinking in the first step, and their interaction in the second step. The results are shown in Table 3 and indicate disillusionment toward authorities as

the only significant predictor of all criterion variables. Cognitive reflection as a measure of rational thinking had no effects on any of the three components of vaccine attitudes. Furthermore, no interaction effect was identified between cognitive reflection and disillusionment toward authorities.

Within the second regression analysis, which was conducted in the equivalent manner as the first one, the ability to override heuristic thinking was used as the second measure of rational thinking and combined with disillusionment toward authorities (TTA-D) (Table 4). As in the previous analysis, disillusionment toward authorities was identified as significant predictor of all criterion variables. Furthermore, heuristic thinking was identified as a significant predictor, but only for the affective and cognitive component of vaccine attitudes, and not for the behavioral component. Finally, the interaction between disillusionment toward authorities and heuristic thinking was significant for the cognitive and behavioral attitude components, but

**TABLE 2** Correlation matrix of the tested variables

	2	3	4	5	6
Vaccine affect ATV (1)	.74**	.52**	-.08**	-.30**	-.73**
Vaccine cognition VHS (2)		.70**	-.16**	-.34**	-.82**
Vaccine behavior (3)			-.04	-.23**	-.58**
Cognitive Reflection CRT (4)				.26**	.17**
Heuristic thinking (5)					.34**
Trust Towards Authorities-Disillusionment TTA-D (6)					

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

**TABLE 3** Results of hierarchical regression analyses using vaccine affect, cognition and behavior as criteria

		Predictors	Criteria		
			Affect	Cognition	Behavior
Step 1	$\beta$	TTA-D	-.740**	-.817**	-.583**
		CRT	.034	-.023	.048
	$R$	.735	.821	.577	
	$R^2$	.540	.674	.333	
	$F$ (df)		522.239**	916.496**	205.006**
			(2)	(2)	(2)
Step 2	$\beta$	TTA-D	-.740**	-.817**	-.583**
		CRT	.043	-.023	.047
		TTA-D*CRT	-.005	.002	.009
	$R$		.735	.821	.577
	$R^2$		.541	.674	.333
	$\Delta R^2$		.000	.000	.000
	$F$ (df)		347.801	610.320**	136.558**
			(3)	(3)	(3)
	$BF_{10}$		0.05	0.04	0.07

Note:  $\beta$ —standardized regression coefficient;  $R$ —multiple regression coefficient;  $R^2$ —variance explained by the predictors;  $\Delta R^2$ —change in  $R^2$ ;  $F$ — $F$  ratio;  $df$ —degrees of freedom;  $BF_{10}$ —Bayes factor indicating how much the model with interaction is favored by the data compared to the model without the interaction.

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

**TABLE 4** Results of hierarchical regression analyses using vaccine affect, cognition and behavior as criteria

		Predictors	Criteria		
			Affect	Cognition	Behavior
Step 1	$\beta$	TTA-D	-.713**	-.797**	-.560**
		Heuristic thinking	-.064**	-.071**	-.044
	$R$	.737	.824	.577	
	$R^2$	.543	.678	.333	
	$F$ (df)	526.860	934.790**	204.122**	
		(2)	(2)	(2)	
Step 2	$\beta$	TTA-D	-.711**	-.791**	-.547**
		Heuristic thinking	-.066**	-.079**	-.058
		TTA-D*Heuristic thinking	.015	.044*	.076**
	$R$	.737	.825	.582	
	$R^2$	.543	.680	.338	
	$\Delta R^2$	.000	.002*	.006**	
	$F$ (df)	351.131**	627.857**	139.315**	
			(3)	(3)	(3)
	$BF_{10}$	0.06	0.47	2.04	

Note:  $\beta$ —standardized regression coefficient;  $R$ —multiple regression coefficient;  $R^2$ —variance explained by the predictors;  $\Delta R^2$ —change in  $R^2$ ;  $F$ — $F$  ratio;  $df$ —degrees of freedom;  $BF_{10}$ —Bayes factor indicating how much the model with interaction is favored by the data compared to the model without the interaction. \* $p < .05$ . \*\* $p < .01$ .

not for the affective component. However, the amount of variance explained by this interaction was modest (0.2% for the cognitive and 0.6% for the behavioral component). Low Bayes factors further indicated that the data did not favor the model with an interaction included any better than the model without it, suggesting that the interactive effects of heuristics and disillusionment are practically negligible.

To get a clearer picture of the effects of rationality variables on vaccine attitudes, we conducted some additional exploratory analyses. First, we wanted to investigate the correlations between individual CRT and heuristics items and vaccine attitudes components. This was motivated by two things: (a) three of the CRT items that we used were not from the original CRT (Frederick, 2005), and we wanted to see whether the magnitude of the correlations between CRT items and vaccine attitudes differs; (b) the content of one of the heuristics (omission bias) was closely related to the topic of vaccination while the other two were more general, and we wanted to see whether this heuristic will therefore be more strongly related to vaccine attitudes in comparison with the other two. We report these correlations in the supporting information, Table S2.

Regarding the CRT items, there were no substantial differences in the magnitude of their relationship with the three components of vaccine attitudes. It seems that the CRT is not a particularly good predictor of vaccine attitudes regardless of the items that are used. In contrast, the correlations between the omission bias as assessed with a vaccination vignette and vaccine attitude components were substantially greater than the correlations between the other two heuristics and vaccine attitude components. This implies that “general” rationality (as assessed by the CRT and general heuristics) affects the

vaccine attitudes rather modestly, but that “content specific” rationality (in this case the ability to resist the omission bias in the decision to vaccinate) could have a greater impact. Therefore, we redid the previously reported regression analyses, only this time instead of a total heuristics score, we included only the omission bias as a predictor. The results of these analyses are reported in the Table 5.

As can be seen from the table, all the three interactions were significant. However, the Bayes factor favors the model with an interaction included over the one without the interaction only for the cognitive and behavior component. Specifically, there is modest evidence in favor of the interaction model in case of cognitive component ( $BF = 5.94$ ) and quite strong evidence for the interaction model in case of behavior ( $BF = 4,065,000$ ) where the interaction model explained an additional 2.8% of variance over the model without an interaction. We show the interaction that were favored by Bayes factor (cognitive and behavior component) in Figures 1 and 2. It is shown that the ability to resist omission bias (i.e., if the data indicate that vaccination is beneficial for children, one will rather vaccinate their children than do nothing just to be sure that potential bad outcomes of vaccination do not happen) is related with more positive cognitions, affects and behaviors regarding the vaccination. This effect was especially pronounced for the individuals that are highly disillusioned by the authorities.

## 4 | DISCUSSION

The present study investigated the association of parental attitudes toward childhood vaccination and their ability to engage in rational

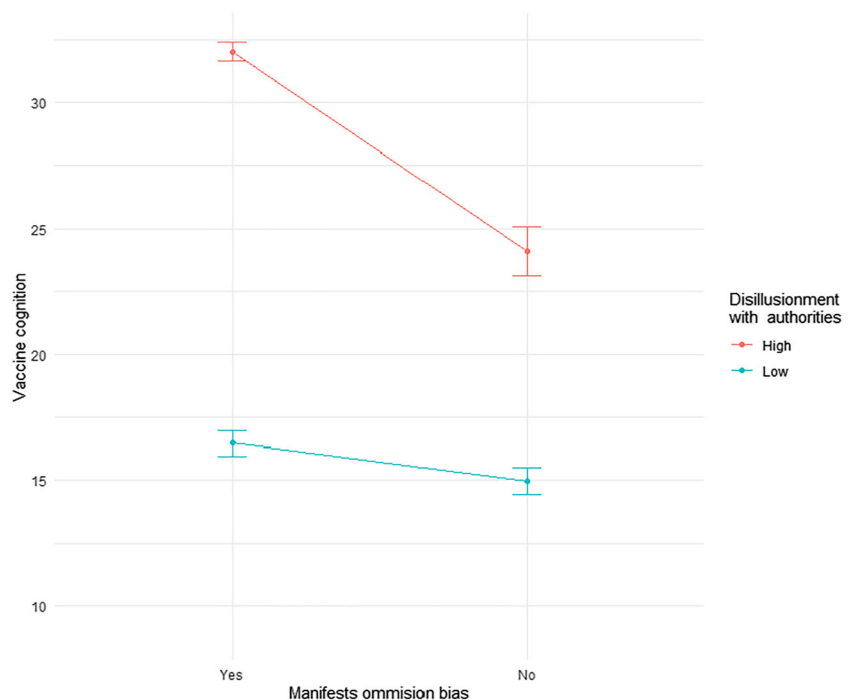
**TABLE 5** Results of hierarchical regression analyses using vaccine affect, cognition and behavior as criteria and omission bias as predictor

		Predictors	Criteria		
			Affect	Cognition	Behavior
Step 1	$\beta$	TTA-D	-.690**	-.791**	-.537**
		Omission bias	-.115**	-.079**	-.100**
	$R$	.742	.824	.583	
	$R^2$	.551**	.679**	.339**	
	$F$ (df)	543.870	938.369	210.435	
		(2)	(2)	(2)	
Step 2	$\beta$	TTA-D	-.715**	-.820**	-.616**
		Omission bias	-.330**	-.332**	-.813**
		TTA-D*Omission bias	.230*	.273**	.766**
	$R$	.744	.826	.607	
	$R^2$	.553**	.683**	.368**	
	$\Delta R^2$	.003*	.004**	.028**	
	$F$	366.039	635.581**	158.708	
	(df)	(3)	(3)	(3)	
	$BF_{10}$	0.61	5.94	4,065,000	

Note:  $\beta$ —standardized regression coefficient;  $R$ —multiple regression coefficient;  $R^2$ —variance explained by the predictors;  $\Delta R^2$ —change in  $R^2$ ;  $F$ — $F$  ratio;  $df$ —degrees of freedom.

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

**FIGURE 1** The contribution of trust toward authorities (disillusionment, Trust Towards Authorities–Disillusionment Scale, TTA-D) and ability to resist omission bias on vaccine cognition (error bars represent standard errors)

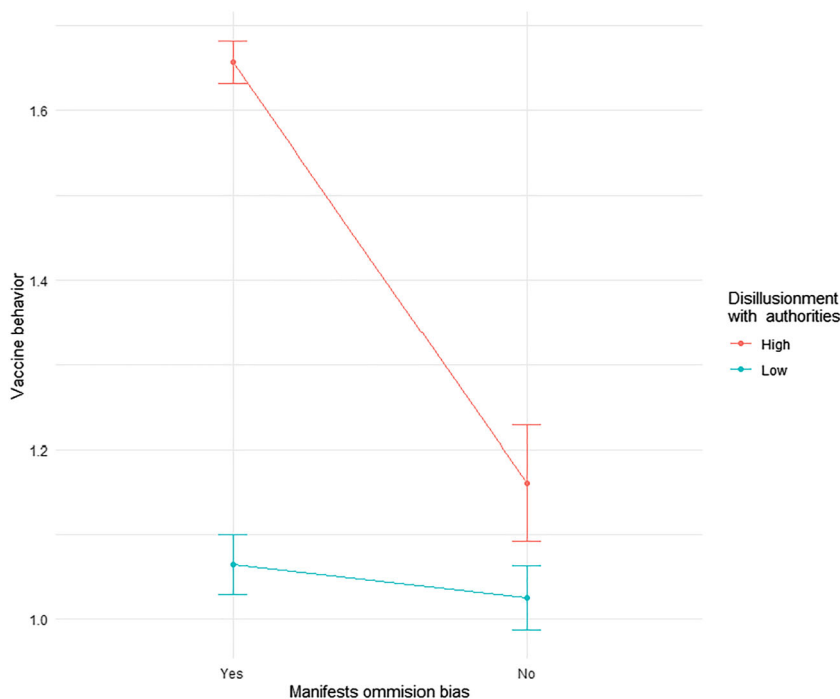


thinking. In doing so, we tested two opposing hypotheses regarding the impact of rationality, namely, the bounded and expressive rationality approach, on vaccine attitudes that were operationalized according to the tripartite attitude model as variables reflecting the affective, cognitive, and behavioral attitude components. Furthermore, cognitive reflection and the ability to override heuristic thinking were used as measures of rational thinking, together with

disillusionment toward authorities, a well-established general tendency impacting vaccine attitudes that was hypothesized to serve as an identity-forming factor by which attitudes could be polarized, according to the expressive rationality hypothesis.

The obtained results indicate disillusionment toward authorities to be a significant predictor of vaccine attitudes in all components, and a much stronger predictor of vaccination than general rational





**FIGURE 2** The contribution of trust toward authorities (disillusionment, Trust Towards Authorities–Disillusionment Scale, TTA-D) and ability to resist omission bias on vaccine behavior (error bars represent standard errors)

skills, suggesting that parents who think or feel negatively toward vaccination and avoid vaccination hold more disillusionment toward authorities. Thus, these parents are more disillusioned, for example, feel disappointed, tricked or deceived by the government and pharmaceutical industries involved in vaccination, which is a confirmation of different previous studies (Jolley & Douglas, 2014b). This effect may be related to the so-called *vaccine-confidence gap*, *crisis of public trust* or *vaccine backlash* phenomenon (Larson et al., 2011) that occurs because of the fact that, in abundance of both pro and anti-vaccination information in the media, parents often get exposed to conflicting messages and lack reliable guides for resolving the contradictions. This results in disillusionment with the government, academia, health professionals, or vaccine manufacturers, which is influenced by a number of different factors such as celebrities' endorsement of anti-vaccination attitudes or the existence of various self-organized social media groups promoting vaccination hesitancy (Larson et al., 2011).

With respect to our primary goal of testing the alternative rationality hypotheses regarding the relevance of rational thinking for vaccination attitudes, our results support the hypothesis stemming from bounded rationality and not from expressive rationality. When preparing the present study, we specifically hypothesized that a positive association between rationality and vaccine attitudes, which is stronger for parents high in disillusionment than those low in disillusionment, would speak in favor of the bounded rationality theory which is supported by the obtained results.

Interestingly and contrary to our predictions, the obtained results showed that vaccine attitudes were predicted only by the omission bias as assessed with a vaccination vignette and not by other heuristics and biases tasks nor cognitive reflection as general rationality

measures. This implies that vaccine hesitant parents do not differ in their general rationality skills, that is, the ability to resist different heuristics and biases, and are not any less skilled in cognitive reflection. Furthermore, it means that vaccine hesitant parents are prone to biases and errors only in the specific content laden decision on child vaccination. This also supports the line of thinking some authors reported when arguing against combining performance on heuristics tasks into a single measure because of the great diversity among the tasks themselves, which implies they do not measure a single underlying construct (Aczel et al., 2016).

Considering the robust effect of disillusionment toward authorities upon vaccine attitudes, this interaction of disillusionment and a vaccine specific omission bias is particularly interesting. We found that parents low in disillusionment toward authorities hold less negative vaccine attitudes regardless of their performance on the omission bias. In other words, parents who hold lower disillusionment toward authorities, that is, feel trust, showed more positive vaccine related beliefs and tended to vaccinate their children more regularly regardless of their ability to correctly reason in the omission bias task. On the other hand, we found that parents high in disillusionment tended to be more accepting of vaccines the greater their ability to override omission bias was. Therefore, it seems that greater proneness toward rational thinking in the specific content of vaccines can, to some extent, decrease the negative effects of disillusionment toward authorities in forming vaccine attitudes. This moderating effect is identified for all the vaccine attitude components. That suggests that more rational parents have both more positive beliefs as well as more positive emotions toward vaccination, and more regularly vaccinate their children. These results further corroborate the role of omission bias in vaccine attitudes, which was challenged in some studies (Connolly & Reb, 2003). Overall, the results



indicate how context specific rationality impacts the directionality of individuals' attitudes, such that more rational parents have attitudes closer to the normative, that is, more positive attitudes toward vaccination, whereas less rational individuals hold stronger negative attitudes toward vaccination, that is, diverge from the normative. Such a notion is in line with various research from bounded rationality theory which shows how rationality is related to many different important real life decisions (Baron et al., 2006; Hastie & Dawes, 2001; Lichtenstein & Slovic, 2006). This suggests that heuristic errors in thinking lead to decisions which are harmful for health, for example, avoiding vaccination. It also resonates with a recent systematic review of heuristics in medical decision making which identified various types of heuristics in this context (Blumenthal-Barby & Krieger, 2015). Therefore, the ability to correctly reason by not succumbing to the omission bias, up to a certain extent, serves as a protective factor against disillusionment toward authorities involved in vaccination, contributing to less negative attitudes in rational parents.

The question which arises is why vaccine hesitant parents do not differ on cognitive reflection and general heuristics tasks from non-hesitant ones. Although cognitive reflection has so far been identified as an important factor in predicting various thinking tasks (Toplak et al., 2014), for example, probabilistic prediction (Koehler & James, 2010) or non-superstitious thinking (Pennycook et al., 2012), and a moderator in polarizing political attitudes (Kahan et al., 2012), such predictive and moderating effects were not identified in the present study. The reason for this might be that cognitive reflection has a complex interrelationship with a range of different and seemingly unrelated sets of abilities, including cognitive ability (Frederick, 2005), working memory (Toplak et al., 2011), numeric abilities (Sinayev & Peters, 2015), and thinking dispositions (Appelt et al., 2011). Furthermore, the associations of cognitive reflection with different measures seem to be sensitive to the context in which they are investigated (Erceg & Bubic, 2017) and even the participants' gender (Campitelli & Gerrans, 2014). Overall, parents with negative versus positive vaccine attitudes do not seem to differ in their ability to think analytically and deliberately to correct the intuitive wrong answers. The same result has been demonstrated in one earlier study investigating cultural and psychological factors in vaccine attitudes (Browne et al., 2015). These results imply that parents with negative vaccine attitudes are not less skilled at analytical reasoning about scientific facts and evidence regarding vaccination, which resonates with the notion that parental education does not directly determine vaccine attitudes (Gowda & Dempsey, 2013). On the other hand, we found parents with more negative beliefs and ATV to be less skilled in overriding omission bias, which is also in line with different previous findings (Jacobson et al., 2007). We suggest that negative attitudes toward vaccination emerge a result of domain-specific reasoning errors as measured by the omission bias, and not because of intuitive, fast and unadvised reasoning which cognitive reflection would be able to correct. The answer to why vaccine hesitant parents differ on omission bias and not cognitive reflection might furthermore lie in the distinct context of this decision. The decision on vaccinating children is of a distinct type, as it is a decision individuals make not for

themselves but for another person (parent for child), and making decision for others as opposed to deciding for oneself is shown to have different underlying reasoning patterns (Zikmund-Fisher et al., 2006).

Furthermore, the decision on children vaccination represents a type of a health choice in which the decision making process is highly involving, and is therefore burdened with other underlying factors (Wroe et al., 2004), especially its emotional relevance which is related to the processing of the so-called *System 1* (Stanovich & West, 2000). Related to this, studies have shown that some people ignore objective possibilities of events only in emotionally important decisions (Suter et al., 2015). That implies that people have the appropriate general potential to reason about risk, but this ability seems to be somehow suppressed in emotionally important decisions, where they are more sensitive to the possibility and not the probability of an event. In other words, in emotionally important decisions some individuals do not reason about the probability of a negative event, that is, how likely vaccine side-effects are, but its possibility, whether it can happen or not, leading to the dichotomization of the decision outcome. For these reasons, parental decisions on vaccinating children can be particularly skewed and more prone to biased reasoning than other types of decisions. The importance of emotions in vaccination uptake in Croatia was also demonstrated in previous research in which negative emotions toward vaccination were found to be a very strong predictor of vaccine uptake as well as beliefs in vaccine related conspiracy theories (Tomljenovic et al., 2020). Moreover, our results can be explained in the light of other dual-processing theories (Reyna, 2008a, 2008b), which explain the processing origins of errors and biases in medical decision making and emphasize how medical information should appeal with gist-based intuitions.

Although our results do not support the expressive rationality hypothesis, they do not exclude the possibility that other identity-forming factors, besides trust toward authorities, might contribute to the polarization of vaccine attitudes. For example, negative attitudes toward vaccination are also often associated with parental moral values (Amin et al., 2017), religious views (McKee & Bohannon, 2016), parenting styles (Smyth & Craig, 2017), as well as biomedical beliefs (Cruz Piqueras et al., 2017). A recent study also showed other psychological factors besides trust, for example, collective responsibility, predict vaccine attitudes (Betsch et al., 2018). Therefore, such factors might represent cultural values which could potentially contribute to the polarization of vaccine attitudes and are suggested as important avenues for future research. Overall, our findings indicate parental vaccine attitudes to be complex, explaining why interventions aiming at lowering negative vaccine attitudes have so far shown limited effectiveness (Jarrett et al., 2015). This is especially relevant for those interventions that focused on reducing knowledge gaps (Sadaf et al., 2013), as vaccine avoiding parents do not seem to lack the skills necessary for reasoning with scientific facts. Contrary to this, hesitant parents might invest a lot of time and effort in their decision, but do so based on inadequate and faulty criteria that include emotional reactions and vividness of anecdotal stories. Moreover, our findings suggest that building trust in authorities could be a potentially beneficial strategy for addressing vaccine hesitancy.

In interpreting the results obtained in the present study, several limitations should be kept in mind. First, all the data are correlational and based on self-reports which have been shown to be associated with a number of biases (McDonald, 2008; Paulhus & Vazire, 2007). Also, our sample predominantly included Croatian women and, as some studies point to gender differences in this context (Scherer et al., 2018), it is advised to test these findings on a more gender-balanced sample, as well as in other countries. Next, it would also be important to replicate these findings using other biases tasks with a vaccination vignette, apart from the omission bias. In this context, it would be interesting to generate novel causal base rate and outcome bias tasks with content specific to vaccination and compare it to the general content tasks. Apart from vaccine specific biases, we also propose testing a non-vaccination, or even a non-health, version of omission bias. This approach would more directly address the key question—is there any contribution of a personal propensity to think making heuristic bias errors to vaccine hesitancy. Moreover, in this study we used several single item measures, as opposed to using an inventory that measures decision making competency and rationality more broadly. Finally, regarding external validity, the generalizability of our results is threatened by a biased sample with volunteers of similar demographic background who were, as mentioned, almost all women, as well as several limitations associated with online questionnaires, such as selection and response bias (Greenacre, 2016). Nevertheless, the obtained results represent an important contribution to the understanding of vaccine attitudes as a public health problem and have the potential to be used as a basis for developing strategies aimed at educating parents for better health decision making, thus contributing to the rationalization of costs in healthcare, reduction of preventable diseases and empowerment of patients in taking responsibility for their health.

To conclude, the results obtained in the present study demonstrate that people who hold negative attitudes toward vaccination are equally skilled in reasoning on general rationality measures, for example, cognitive reflection and heuristics and biases tasks, but are more prone to a vaccine specific omission bias. The ability to resist omission bias can decrease the negative contribution of disillusionment toward authorities which overall strongly predicts vaccines attitudes, and this ability serves as a protective factor which contributes to more positive vaccine attitudes and a greater vaccine uptake. These findings are important in our understanding of vaccine hesitancy and developing interventions aimed at increasing vaccination rates, which is even more needed considering the covid-19 pandemic.

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None to declare.

#### CONFLICT OF INTEREST

None to declare.

#### DATA AVAILABILITY STATEMENT

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

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## SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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