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Explaining the Mechanism Behind mRNA Vaccines Influences Perceived Vaccine Effectiveness but not Vaccination Intentions

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A Randomized Experiment

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Abstract

Vaccine effectiveness and safety concerns can prevent people from receiving their first Covid-19 vaccines or boosters. Understanding the vaccine mechanism may lead people to perceive vaccine effectiveness appropriately. This study tested whether helping people understand the vaccine's mechanism could improve their perceived vaccine safety and effectiveness. In a preregistered study, *N* = 1,548 unvaccinated or non-boosted participants were randomly presented with one of three communication formats: a fact box (a benefit-risk profile in tabular format; control condition), an expository text (i.e., a purely factual explanation) plus fact box, or an analogy plus fact box. Participants rated the vaccine's effectiveness in preventing a Covid-19 disease, their perceived risk of getting vaccinated, and their intention to get vaccinated or boosted (depending on their vaccination status). Reading either additional text about the vaccines' mechanism increased participants' effectiveness ratings for the vaccine to prevent Covid-19 but did not affect risk ratings or vaccination intentions. The participants' vaccine-related perceptions and intentions did not differ between the two

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text types. Elaborating on the vaccine's mechanism of protection, in addition to presenting the benefit-risk profile of a vaccine, can lead people to perceive the vaccine effectiveness as slightly higher, yet it is insufficient to increase vaccination intentions.

Keywords

Vaccine hesitancy, educational intervention, analogy, SARS-CoV-2-pandemic, informed decision-making, fact box.

When health authorities worldwide approved the first mRNA vaccine at the end of 2020 (Lamb, 2021), the public was introduced to mRNA technology. While both laypeople and medical personnel knew little about the mRNA vaccine mechanism (Holzmann-Littig et al., 2021; Leuker et al., 2022), parts of the public voiced concerns about the vaccine's effectiveness and safety, especially those who were unvaccinated or remained without a booster against Covid-19 (Attia et al., 2022; Kricorian et al., 2022; Lazarus et al., 2022; Lin et al., 2020; Wang et al., 2021). As people's perceptions about the vaccine are associated with their decision to vaccinate (Lin et al., 2020; Wang et al., 2021), this study aims to test whether explaining the underlying mechanism of how the vaccine works could adjust vaccine effectiveness perceptions accordingly.

Vaccination as Response Strategy Within the Protection Motivation Theory

Covid-19 infection is understood as a health threat, and vaccination is a response strategy against infection. Many health behaviour theories, such as protection motivation theory (PMT), incorporate both components to explain health behaviour (Maddux & Rogers, 1983; Rogers, 1975). According to the PMT, threat perceptions involve beliefs about the severity of a threat and vulnerability to a threat. The appraisal of a response strategy includes beliefs about response efficacy, response costs, and self-efficacy. Across a wide array of health behaviours, including vaccination, the appraisal of the response strategy has been found to have greater predictive validity for intended and actual behaviour than for the threat component (Floyd et al., 2000; Milne et al., 2000; Ort & Fahr, 2018; Schulz & Hartung, 2021). Thus, presenting vaccination as an effective response strategy for preventing a (severe) Covid-19 infection could more likely induce health behaviour than emphasizing threats of the infection. For example, one study comparing messages about collective benefits, personal benefits, pandemic seriousness, and vaccine safety showed that highlighting the personal vaccine benefit in terms of averting serious disruptions in everyday life appealed to strongly hesitant individuals (Freeman et al., 2021). Previous research showed that people are not only sensitive to qualitative claims about Covid-19 vaccines' effectiveness but also in terms of numbers. When presented with two vaccines with different benefit profiles and vaccination schemes, people chose a two-dose vaccine over a one-dose vaccine when the two-dose vaccine offered greater protection (Kreps & Kriner, 2022). Further, contrasting a Covid-19 vaccine with a less effective flu vaccine increased the intention to get vaccinated against Covid-19 (Davis et al., 2022).

Another way to illustrate the response efficacy is to contrast the probability of contracting Covid-19 in vaccinated and unvaccinated people given that the individuals become exposed to the virus. Fact boxes (McDowell et al., 2016) are an evidence-based format to provide risk-benefit information that can enable informed health decisions (McDowell et al., 2019)–and allow this type of comparison. Fact boxes on vaccination, for example, provide infection numbers and health outcomes in both vaccinated and unvaccinated groups and thus make the outcomes of both choice options–vaccination and non-vaccination–easily comparable. Studies have demonstrated that fact boxes are easily comprehensible and can foster Covid-19 vaccine confidence (Brick et al., 2020; Rebitschek et al., 2022). People who were sceptical or undecided about having the vaccine evaluated the Covid-19 vaccine more favourably when they comprehended the information presented in a fact box (Rebitschek et al., 2022).

However, how people interpret objective information, such as numbers, depends on their knowledge and attitudes about the topic and how well they understand and use this information while reasoning (Reyna, 2012; Trevors, 2022). For example, when objective information conflicts with pre-existing beliefs, people are less likely to update their knowledge according to this information (Trevors, 2022). People's pre-existing beliefs also influence their judgment of health information they encounter for the first time (Chang et al., 2012). In the case of vaccination, confidence in the vaccine's effectiveness, safety, and the medical system constitute important pre-existing beliefs (Betsch et al., 2018; Brewer et al., 2017). Another example of influencing factors on the interpretation of objective information is cognitive skills. When using a fact box, individuals with higher numeracy understand the numbers better (Brick et al., 2020). Individuals who struggle to interpret numbers (i.e., low numerates) tend to derive less precise affective meaning from numbers and are therefore more influenced by affective information from potentially irrelevant sources (Peters et al., 2006). Since mRNA vaccines are a recent technology, concerns arising from questions and knowledge gaps about mRNA vaccine mechanisms can be alternative sources of affect that may foster misperceptions about vaccine effectiveness. Therefore, explaining the vaccine mechanism could enhance the perceived response efficacy. However, the provided explanations about the vaccine mechanism should be particularly comprehensible since hesitant people especially disagreed that information about Covid-19 vaccines is easy to understand (Kricorian et al., 2022; Seefeld et al., 2022). Thus, vaccine communication could harness methods from general health communication that make complex information easy to understand, such as explaining complex information with analogies or metaphors.

Using Analogies to Facilitate Understanding

Analogies and metaphors can be employed to facilitate the understanding of health concepts (Ervas et al., 2022; Galesic & Garcia-Retamero, 2013). Holyoak and Stamenković define a metaphor as a figure of speech that describes "one thing in terms of something else that is conceptually very different" (Holyoak & Stamenković, 2018, p. 641). These comparisons can involve systematic correspondences, shared features, or associations between two entities (Holyoak & Stamenković, 2018). By contrast, the definition of analogy is narrower. According to Gentner and Smith, an analogy focuses only on the associations between two entities: the "similarity in relational structure" (Gentner & Smith, 2013, p. 2). Thus, in the following, we use the term analogy for our study because we want to focus on the similarity based on the relation of two entities.

Analogies facilitate the comprehension of new concepts by drawing on known concepts. An analogy maps selected elements of the target (new domain) onto the source's elements (known domain) to create a framework for understanding the target (Bostrom, 2008; Gentner & Smith, 2013; Landau et al., 2019). This process is called analogical mapping and helps build a mental model of the target (i.e., an internal representation of something (Jones et al., 2011)). For example, the new concept of a vaccine mechanism (target) can be compared to the known concept of a 'Wanted' picture (source): Laypeople know from everyday experiences that a 'Wanted' picture describes the appearance of a dangerous person; thus, concerned parties are prompted to prepare for a confrontation with this antagonist. This knowledge can be mapped to vaccines as targets: a vaccine shares 'Wanted' pictures of a virus with the immune system to trigger an immune reaction.

Research shows that analogies can be useful in communicating new health concepts because they are assumed to draw the recipient's attention, stimulate elaboration, and facilitate comprehension (Ervas et al., 2022; Galesic & Garcia-Retamero, 2013; Van Stee, 2018). For example, using "bees in a beehive" as a metaphor for the collective effort to contribute to herd immunity via vaccination was more understandable and convincing than an expository, purely factual text (Ervas et al., 2022). An analogy is helpful when the source is a well-known domain and easy to visualize, as well as enables an accurate and purposeful mapping on the target (Semino, 2021). However, the comparison is less effective if the reader holds a strong attitude about the source or target domains (Semino, 2021; Thibodeau et al., 2019).

The capability of analogies to catch the reader's attention, and facilitate and deepen the understanding of the described health concept can be beneficial in presenting vaccination as an effective response strategy. Attention and reading comprehension are important factors in information processing, such as forming and updating a mental model of a response strategy (Feng et al., 2013; Stevens & Bavelier, 2012; Woolley, 2010). As postulated in the PMT, the evaluation of a response strategy influences behavioural intentions (Floyd et al., 2000; Milne et al., 2000; Ort & Fahr, 2018; Schulz & Hartung, 2021). Thus, employing an analogy to explain the response efficacy could not only strengthen the perception of the response strategy's effectiveness but also have a greater effect on the vaccination intention than an expository text.

Current Study

In a preregistered study, we tested whether the expository text and the analogy can (1) increase the perceived effectiveness of preventing a Covid-19 disease, (2) reduce the perceived risk of vaccination, and (3) increase the intention to vaccinate, compared to a fact box about the Covid-19 vaccine only. We further explored the influence of vaccination status and how well the study materials were understood and received.

Hypotheses

Laypeople are sensitive to information about vaccine benefits when appraising vaccination as a response strategy (Davis et al., 2022; Freeman et al., 2021; Kreps & Kriner, 2022; Mostafapour et al., 2019). Based on this evidence, we expected that elaborating on the vaccine mechanism and benefits would enhance the effectiveness perception.

> *H1:* Participants who read a text (expository text or analogy) explaining the mRNA mechanism and the personal vaccine benefit in addition to the fact box perceive higher vaccine effectiveness than participants who read only a fact box. [The effectiveness hypothesis]

Previous research has shown that vaccine benefits and risks are not evaluated independently from each other: vaccines perceived as highly effective are also considered to be of lower risk

(Alhakami & Slovic, 1994; European Medicines Agency, 2012; Mostafapour et al., 2019). The affect heuristic and risk-as-feelings framework explain this phenomenon (Slovic et al., 2007; Tompkins et al., 2018) by proposing that general affective judgments of an object or action systematically affect how the respective benefits and risks are evaluated (Alhakami & Slovic, 1994; Finucane et al., 2000). Thus, we expected that elaborating on the personal vaccine benefit would also affect the perceived risks.

> *H2:* Participants who read a text (expository text or analogy) explaining the mechanisms and the personal vaccine benefit in addition to the fact box report a lower perceived risk of vaccination than participants in the fact box-only condition. [The risk hypothesis]

Analogies can help form mental models (Jones et al., 2011), such as perceptions about response strategies. Thus, using an analogy should enhance the elaboration and comprehension of vaccination as an effective response strategy, which informs behavioural intention (Ort & Fahr, 2018; Schulz & Hartung, 2021). Moreover, analogies can visualize abstract concepts and create an image in one's mind (Duit, 1991). More vivid information, in turn, is more likely to influence intentions than abstract information (Blondé & Girandola, 2016). For example, comparing the influenza virus to a beast (vs. no analogy) increased the intention to get a flu shot (Scherer et al., 2015). Therefore, we expected the analogy to increase the intention to get a Covid-19 vaccine.

> *H3:* Participants who read an analogy in addition to the fact box indicate a higher intention to get vaccinated than participants who read the expository text or only the fact box. [The intention hypothesis]

Methods

The preregistration, materials, data set, and analysis script for this study are available in the Open Science Framework repository (Felgendreff et al., 2023).

Participants and Design

We implemented a one-factorial between-subjects design with three conditions: (1) fact box only (control), (2) expository text plus fact box, or (3) analogy plus fact box. We used stratified randomization to balance the potentially confounding variables vaccine confidence (as proxy for attitude toward Covid-19 mRNA vaccines) and numeracy (as a proxy for cognitive skills to understand numeric information). Both variables influence the comprehension and perceptions of vaccination information (Brick et al., 2020; Trevors, 2022). Thus, participants were stratified into 14 subgroups resulting from their responses to a numeracy item (correct/false) crossed with a vaccination confidence item (seven-point scale). The participants in each stratified group were randomly assigned to one of the three conditions. We chose this type of randomization since simple randomization cannot exclude an imbalance of confounding variables across the conditions (Morgan & Rubin, 2012). By implementing stratified randomization, the three conditions were comparable with regard to the confounding variables and thus reduced the possibility of Type I errors due to imbalanced confounders (Kernan et al., 1999). The a priori sample size calculation for a one-factorial ANOVA with three conditions ($f = .10$, $\alpha = .05$, $1 - \beta = .95$) resulted in $N = 1{,}548$ to detect the expected small effect. Participants aged 18 years and older were recruited from the German online panel Bilendi from September to October 2022.[1] Only individuals who had received no or two doses of the Covid-

19 vaccine (primary vaccination) were eligible to participate, since there was no fact box available to inform once vaccinated individuals about the vaccination outcomes of one dose. To ensure that the fact boxes could be fully seen, participation with smartphones was not possible. Participants who failed an attention check ($n = 201$, as described below) were immediately screened out. The final data set included $N = 1{,}548$ participants (for sociodemographic details, see Table 1 and Supplement, Table S1). The 573 unvaccinated participants had lower confidence in Covid-19 vaccines than the 975 participants who were vaccinated twice (recommended doses for primary protection). The passing rate of the numeracy item was 19% in both groups.

Procedure

The participants rated their infection probability and severity after reading a comprehensive summary of the transmission and disease course of Covid-19. They should then imagine searching for information about vaccine benefits and risks online. They then saw the information materials according to the condition and received several questions (dependent variables). The information material was available at all times when working on the dependent variables. Participants interested in downloading the information material as PDF received the opportunity to do so. Lastly, the debriefing informed the participants about the research question and provided references to more detailed information about Covid-19 and the vaccines.

Materials and Measures

Manipulation

Fact Box. Each participant saw a fact box, as shown in Figure 1, displaying data on the mRNA vaccine's benefits and adverse events (Harding Center for Risk Literacy, 2022). The figures of the vaccine outcomes were listed as numbers and illustrated in color-coded icon arrays. The fact box for unvaccinated participants showed the outcomes of the BioNTech/Pfizer Covid-19 vaccine for 1,000 unvaccinated people compared to 1,000 vaccinated people. The fact box for primary vaccinated participants compared the outcomes in the same way for primary vaccinated to boosted people. The potential benefits were (A) fewer Covid-19 cases than in the comparison group, (B) fewer hospitalizations due to severe Covid-19, and (C) fewer long-term consequences of Covid-19. As outcomes vary according to vaccination status and age, the content of the fact box matched participant's vaccination status and age group (below 60 years or 60 years and older). The rates for hospitalizations due to severe Covid-19 and moderate vaccine reactions were higher in the age group 60 years and older.

The potential harms comprised three different types of adverse events, varying in severity. There were (A) more typical vaccine reactions in the vaccination (booster) group than in the comparison group with no (primary) vaccination. They were described as being unable to participate in everyday life for a few days following vaccination. (B) Temporary severe harm was more (equally) likely in the vaccinated (primary) group than in the unvaccinated (boosted) group, and (C) there was no evidence of permanent harm.

Table 1. Sociodemographic Details for the Final Sample (N = 1,548)

Variable		Distribution parameters						Main Effects	
		Total	Condition			Vaccination Status			
			A	B	C	U	PV	Condition	Vaccination Status
N	*n*	1,548	497	526	525	573	975	N/A	N/A
	(%)	(100.0)	(32.1)	(34.0)	(33.9)	(37.0)	(63.0)		
Age	*M*	43.4	43.4	43.4	43.4	46.5	41.58	$F(2, 1542) < 0.01$, $p = 1.000$, $\eta_p^2 < .01$	$F(1, 1542) = 40.87$, $p < .001$, $\eta_p^2 = .03$, $d = 0.37$
	(SD)	(14.9)	(14.1)	(15.5)	(15.0)	(14.0)	(15.0)		
Gender									
Male	*n*	856	291	273	292	300	556	$\chi^2(4) = 9.92$, $p = .042$	$\chi^2(2) = 4.10$, $p = .129$
	(%)	(55.3)	(58.6)	(51.9)	(55.6)	(52.4)	(57.0)		
Female	*n*	687	205	253	229	270	417		
	(%)	(44.4)	(41.2)	(48.1)	(43.6)	(47.1)	(42.8)		
Diverse	*n*	5	1	0	4	3	2		
	(%)	(0.3)	(0.2)	(0.0)	(0.8)	(0.5)	(0.2)		
School education									
No school leaving certificate	*n*	15	5	6	4	10	5	$\chi^2(10) = 6.97$, $p = .728$	$\chi^2(5) = 17.39$, $p = .004$
	(%)	(1.0)	(1.0)	(1.1)	(0.8)	(1.7)	(0.5)		
Lower track	*n*	144	41	51	52	58	86		
	(%)	(9.3)	(8.2)	(9.7)	(9.9)	(10.1)	(8.8)		
Intermediate track	*n*	528	173	186	169	216	312		
	(%)	(34.1)	(34.8)	(35.4)	(32.2)	(37.7)	(32.0)		
FH [a] entrance qualification	*n*	213	60	67	86	81	132		
	(%)	(13.8)	(12.1)	(12.7)	(16.4)	(14.1)	(13.5)		
University entrance qualification	*n*	619	208	206	205	201	418		
	(%)	(40.0)	(41.9)	(39.2)	(39.0)	(35.0)	(42.9)		
Other school type	*n*	29	10	10	9	7	22		
	(%)	(1.9)	(2.0)	(1.9)	(1.7)	(1.2)	(2.3)		

Table 1. Sociodemographic Details for the Final Sample (*N* = 1,548) [continued]

Variable		Distribution parameters						Main Effects	
		Total	Condition			Vaccination Status			
			A	B	C	U	PV	Condition	Vaccination Status
Vaccination status [b]									
Unvaccinated	*n*	573	186	192	195	573	0	χ^2 (2) = 0.10, *p* = .952	N/A
	(%)	(37.0)	(37.4)	(36.5)	(37.1)	(100.0)	(0.0)		
Primary vaccinated	*n*	975	311	334	330	0	975		
	(%)	(63.0)	(62.6)	(63.5)	(62.9)	(0.0)	(100.0)		
mRNA vaccine received (BioNTech or Moderna) [c]									
Yes	*n*	862	275	300	287	N/A	862	χ^2 (2) = 1.32,	N/A
	(%)	(88.4)	(88.4)	(89.8)	(87.0)		(88.4)	*p* = .518	
No/don’t know	*n*	113	36	34	43	N/A	113		
	(%)	(11.6)	(11.6)	(10.2)	(13.0)		(11.6)		
7C short scale									
Mean score	*M*	3.3	3.3	3.2	3.3	2.4	3.8	*F*(2, 1542) = 0.96,	*F*(1, 1542) = 578.73,
	(SD)	(1.4)	(1.4)	(1.4)	(1.3)	(1.0)	(1.3)	*p* = .383, $\eta_p^2 < .01$	*p* < .001, $\eta_p^2 = .27$, *d* = -1.36
Confidence	*M*	3.4	3.3	3.4	3.4	2.1	4.1	*F*(2, 1542) = 0.08,	*F*(1, 1542) = 472.18,
	(SD)	(2.1)	(2.1)	(2.1)	(2.1)	(1.5)	(2.0)	*p* = .923, $\eta_p^2 < .01$	*p* < .001, $\eta_p^2 = .23$, *d* = -1.23
Numeracy item									
False	*n*	1,250	397	427	426	462	788	χ^2 (2) = 0.36,	χ^2 (1) < 0.01,
	(%)	(80.7)	(79.9)	(81.2)	(81.1)	(80.6)	(80.8)	*p* = .837	*p* = .979
Correct	*n*	298	100	99	99	111	187		
	(%)	(19.3)	(20.1)	(18.8)	(18.9)	(19.4)	(19.2)		

Note. A two-factorial ANOVA (metric variable level; in the case of the variable vaccination status, mRNA vaccine: one-factorial ANOVA) or χ^2-test (nominal variable level) was conducted to test for differences between factor levels. N/A implies that comparison was not possible or reasonable. Conditions: A= Fact box only, B = Expository text, C = Analogy; Vaccination status: U = Unvaccinated, PV = Primary vaccinated. [a] FH is the abbreviation for the German equivalent of ‘University for applied science’. [b] Only the response options that align with the inclusion criteria are displayed. [c] The vaccine manufacturer BioNTech/Pfizer and Moderna were recorded in two separate questions. This variable is the result of combining the answers from both questions. For distribution of the answers to the specific questions about the vaccine manufacturer, see Supplement, Table S1.

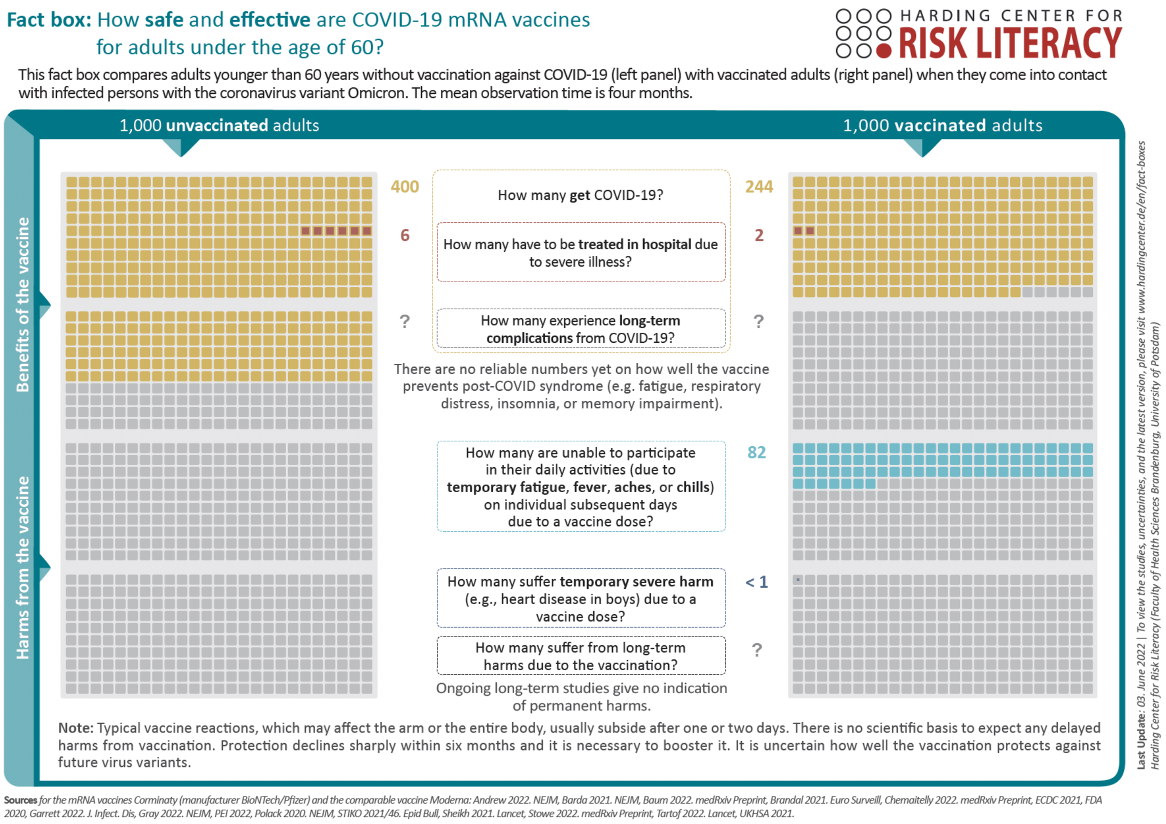

Figure 1. Example of a Fact Box as Provided in the Experiment (Unvaccinated Adults Below 60 Years)

In the *control condition*, a short introduction primed the reader that the fact box summarized scientific studies about how well the mRNA vaccination can prepare the immune system for contact with the omicron variant. The text was rather short (42/44 words) and obtained a readability index (LIX) typical of nonfiction literature ($LIX_{unvaccinated} = 51.0/LIX_{primary = }51.9$) (Lenhard & Lenhard, 2011).

Expository Text. The *expository text* comprised five sections. The first section, ‘The viral infection,’ set the background by taking up the transmission route. The second section, ‘The vaccination,’ explained how the mRNA vaccine supplied the immune system with the necessary information to counteract an infection with the coronavirus. The third section was identical to the text and fact box of the control condition. The fourth section connected the information on how the vaccine works with the information presented in the fact box—that is, which benefits one would miss by omitting the (additional) vaccine dose. Finally, the expository text ended with the bottom line that vaccination prevents many people from contracting and experiencing Covid-19 and ensures that people can go about their daily lives as usual. The expository text was comparably long (310/324 words), and its readability index was typical for nonfiction ($LIX_{unvaccinated} = 54.0/LIX_{primary = }55.2$).

Analogy. The *analogy* condition followed the same outline as the expository text and ended with the same bottom line. The analogy mapped the technical information about vaccines (target) on the source domain of a bank robbery. Accordingly, the coronavirus was pictured as a bank robber, the body as a bank, the immune system as bank security, and the spike protein’s mRNA in the vaccine as a ‘Wanted’ picture of the bank robber. Coffee and Perkins (Coffee &

Perkins, 2021) also used a 'Wanted' picture as an analogy to explain the vaccine mechanism. Although bank robbery is a well-known concept through entertainment media, there has been a steady decline in German crime statistics (Statista, 2023). Given the low likelihood of having experienced an actual robbery, the domain of bank robbery should not elicit strong negative emotions. The analogy text, similar to the expository text, was comparably long (403/421 words), and its readability index was typical for nonfiction ($LIX_{unvaccinated}$ = 54.8/$LIX_{primary =}$ 55.4).

Dependent Variables. The participants indicated how effective they perceived the vaccine to be against infection ("How effective do you think the [third] vaccine [(first booster dose)] is in preventing Covid-19?", words in square brackets for primary vaccinated participants) on a seven-point scale (1 = *not effective at all* to 7 = *very effective*). The perceived effectiveness against severe Covid-19 was assessed in the same format (see Supplement S2 for explorative results). The participants also stated their perceived risk of vaccination ("How risky do you think it would be for you to be vaccinated/ to have a third vaccination against Covid-19 with this vaccine?") on a seven-point scale (1 = *not risky at all* to 7 = *very risky*). The vaccination intention ("How would you decide if you had the opportunity next week to be vaccinated against Covid-19 with this vaccine?") was rated on a seven-point scale (1 = *no way vaccinate* to 7 = *vaccinate in any case*). Furthermore, an objective comprehension test probed how well the participants understood the presented information. The test comprised eight pretested questions (McDonald's ω = .72) that asked participants to find, compare and calculate figures and make inferences (six single-choice questions and two fill-in-the-gap questions). Answers were recoded into correct (1 point) or false (0 points) and summed to an aggregate comprehension score ranging from 0 to 8 points.[2]

Confounding Variables. The Berlin numeracy test single item (median) format assessed numeracy (Cokely et al., 2012). The participants further stated their vaccination readiness (7C short scale, seven items) (Geiger et al., 2021) on a seven-point scale. The vaccine confidence item ("I am convinced the appropriate authorities do only allow effective and safe Covid-19 vaccines," 1 = *strongly disagree* to 7 = *strongly agree*) used for sample stratification was part of the 7C short scale. For details on distributions, see Table 1.

Evaluation of the Material. After reading the information, the participants stated on a seven-point scale their experienced anger and fear while reading the information material and how they evaluated it on six dimensions (appealing, well made, reliable, understandable, convincing, and interesting) (Rössler, 2011).

Attention Check. The participants were informed that failing to correctly answer the question would result in exclusion. They had to choose the coronavirus variant mentioned in the information material from five response options ("To which coronavirus variant does the informational material refer?"; answer options: *Alpha*, *Beta*, *Delta*, *Gamma*, and *Omicron*). The information material was displayed the whole time.

Sociodemographic Variables. Participants provided their age, gender, highest level of school education, and vaccination status. They also indicated whether they had been infected with Covid-19 in the past (Betsch et al., 2022) and whether they believed there was an official vaccination recommendation for their age group. Primary vaccinated participants were asked whether they had received an mRNA vaccine by the vaccine manufacturer BioNTech/Pfizer or

Moderna. For details on distribution, see Table 1 and Supplement, Table S1.

Further Variables. The participants rated their probability of a Covid-19 infection and its expected severity (Betsch et al., 2022) and answered a knowledge test about Covid-19 mRNA vaccines (Holzmann-Littig et al., 2021). They stated their interest in downloading the presented information material and expectations about the new Covid-19 wave in the fall and winter (Betsch et al., 2022). At the end of the survey, participants could comment on the survey in a text field. These variables are not part of the article and are reported only for completeness.

Statistical Analysis

Preregistered one-factorial analyses of variance (ANOVAs) with Helmert contrast were conducted to analyse the hypotheses. The Helmert contrast was selected because it allowed grouping and ordering of the levels of a categorical variable (in this case, condition) in the particular logic required to test the study's hypotheses (van den Berg, 2023). In the case of three conditions, as in this study, the first step compares one condition to the mean of two grouped conditions. In the second step, the two grouped conditions are compared to each other. For the effectiveness and risk hypotheses (H1 and H2), the first Helmert contrast compared the fact box-only group to the two text conditions. The second (explorative) contrast compared the two text conditions to each other. For the intention hypothesis (H3), the analogy condition was compared to the two other conditions; then, the fact box-only condition was (exploratively) compared to the fact box plus expository text condition. Exploratory analyses included vaccination status as an additional factor. All other explorative two-factorial ANOVAs were conducted without Helmert contrast. Nonparametric Kruskal–Wallis tests confirmed all results (see Supplements S3 and S5). Cohen's *d* was used for comparisons between contrasts and vaccination status. Since known confounders were balanced by stratified randomization, we report the results of analyses of covariance in Supplement S4.

Results

Perceived Vaccine Effectiveness of Preventing Covid-19

Figure 2 shows the main results. The results confirmed the effectiveness hypothesis (H1; Figure 2A): The mean perceived vaccine effectiveness of preventing Covid-19 was higher in the conditions in which a text explained the vaccine mechanism (M = 3.6, SD = 2.0, n = 1,051) than in the fact box-only condition (M = 3.4, SD = 2.0, n = 497; F(1, 1,545) = 4.53, p = .033, η^2 < .01, d = -0.14). The Helmert contrast between the two text conditions was not significant (F(1, 1,545) = 0.11, p = .743, η^2 < 01, d = 0.02). The exploratory inclusion of vaccination status in the ANOVA showed that unvaccinated participants (M = 2.3, SD = 1.5, n = 573) reported a lower perceived vaccine effectiveness than primary vaccinated participants (M = 4.3, SD = 1.9, n = 975; F(1, 1,542) = 468.75, p < .001, η_p^2 = .23, d = -1.22; for a graphical visualization, see Supplement S3). The contrast between text conditions and the fact box-only condition remained significant (F(1, 1,542) = 5.90, p = .015, η_p^2 < .01). There was no significant interaction between vaccination status and information material (F(2, 1,542) = 0.34, p = .714, η_p^2 < .01).

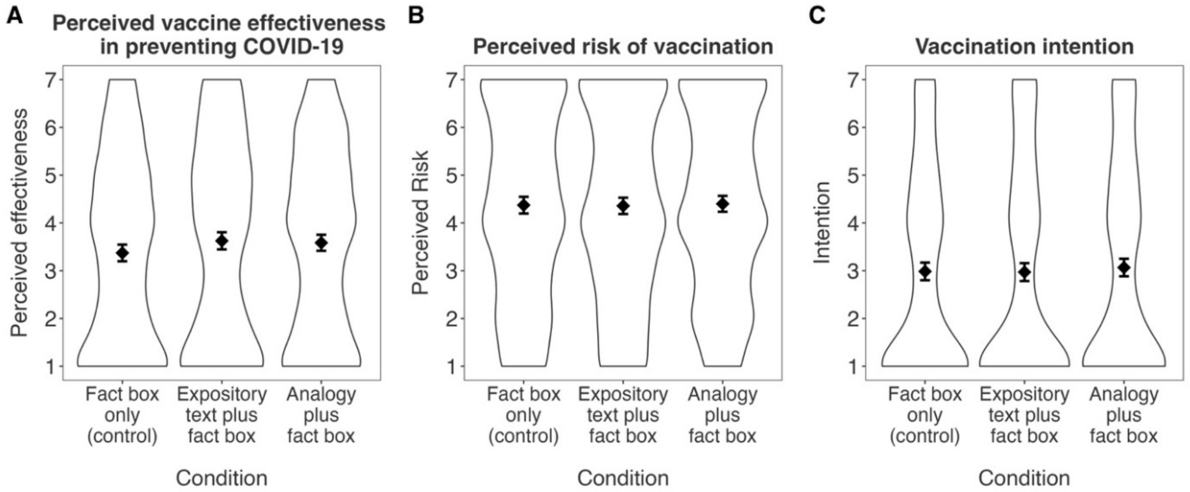

Figure 2. Distribution of Central Dependent Variables Across Conditions

Note. The violin plots visualize the density distributions of the responses. The diamond indicates the group mean, and the whiskers represent the bootstrapped 95% confidence interval. An expository text or an analogy explaining the vaccine benefits through the vaccine mechanism increased the perceived vaccine effectiveness of preventing Covid-19 (A) compared to the control condition (fact box only) but did not affect the perceived risk of vaccination (B) or the vaccination intention (C).

Perceived Risk of Vaccination Against Covid-19

In line with the literature about the inverse relationships of benefits and risks, the perceived risk of getting vaccinated against Covid-19 was negatively correlated with the perceived vaccine effectiveness of preventing Covid-19 ($r = -.51$, $p < .001$). The preregistered one-factorial ANOVA with a Helmert contrast showed, however, that the perceived risk of getting vaccinated against Covid-19 with an mRNA vaccine did not differ between the text conditions ($M = 4.4$, $SD = 2.0$, $n = 1{,}051$) and the control condition ($M = 4.4$, $SD = 2.0$, $n = 497$; $F(1, 1{,}545) < 0.01$ $p = .952$, $\eta^2 < .01$, $d < 0.01$). Therefore, the risk hypothesis (H2) was rejected. The difference between the text conditions was also not significant ($F(1, 1{,}545) = 0.12$, $p = .726$, $\eta^2 < .01$, $d = -0.02$). For exploratory purposes, the vaccination status factor was included. The two-factorial ANOVA revealed only a significant main effect of vaccination status. Unvaccinated participants ($M = 5.6$, $SD = 1.7$, $n = 573$) perceived higher vaccination risks than primary vaccinated participants ($M = 3.7$, $SD = 1.8$, $n = 975$; $F(1, 1{,}542) = 420.41$, $p < .001$, $\eta_p^2 = .21$, $d = 1.18$; all other Fs < 0.64).

Intention to Get Vaccinated Against Covid-19

The preregistered Helmert contrast showed that the mean vaccination intention did not differ between participants who read the analogy ($M = 3.1$, $SD = 2.1$, $n = 525$) and participants who received the expository text or only the fact box ($M = 3.0$, $SD = 2.1$, $n = 1{,}023$; $F(1, 1{,}545) = 0.59$, $p = .443$, $\eta^2 < .01$, $d = -0.05$). Thus, the intention hypothesis (H3) was rejected. There was also no significant difference between the latter two conditions ($F(1, 1{,}545) = 0.01$, $p = .91{,}4$ $\eta^2 < .01$, $d < 0.01$). Exploratory analysis with vaccination status as the second factor showed only a significant main effect. Unvaccinated participants ($M = 1.6$, $SD = 1.2$, $n = 573$) were less inclined to get vaccinated than primary vaccinated participants ($M = 3.8$, $SD = 2.1$, $n = 975$; $F(1, 1{,}542) = 506.42$, $p < .001$, $\eta_p^2 = .25$, $d = -1.30$; all other Fs < 0.40).

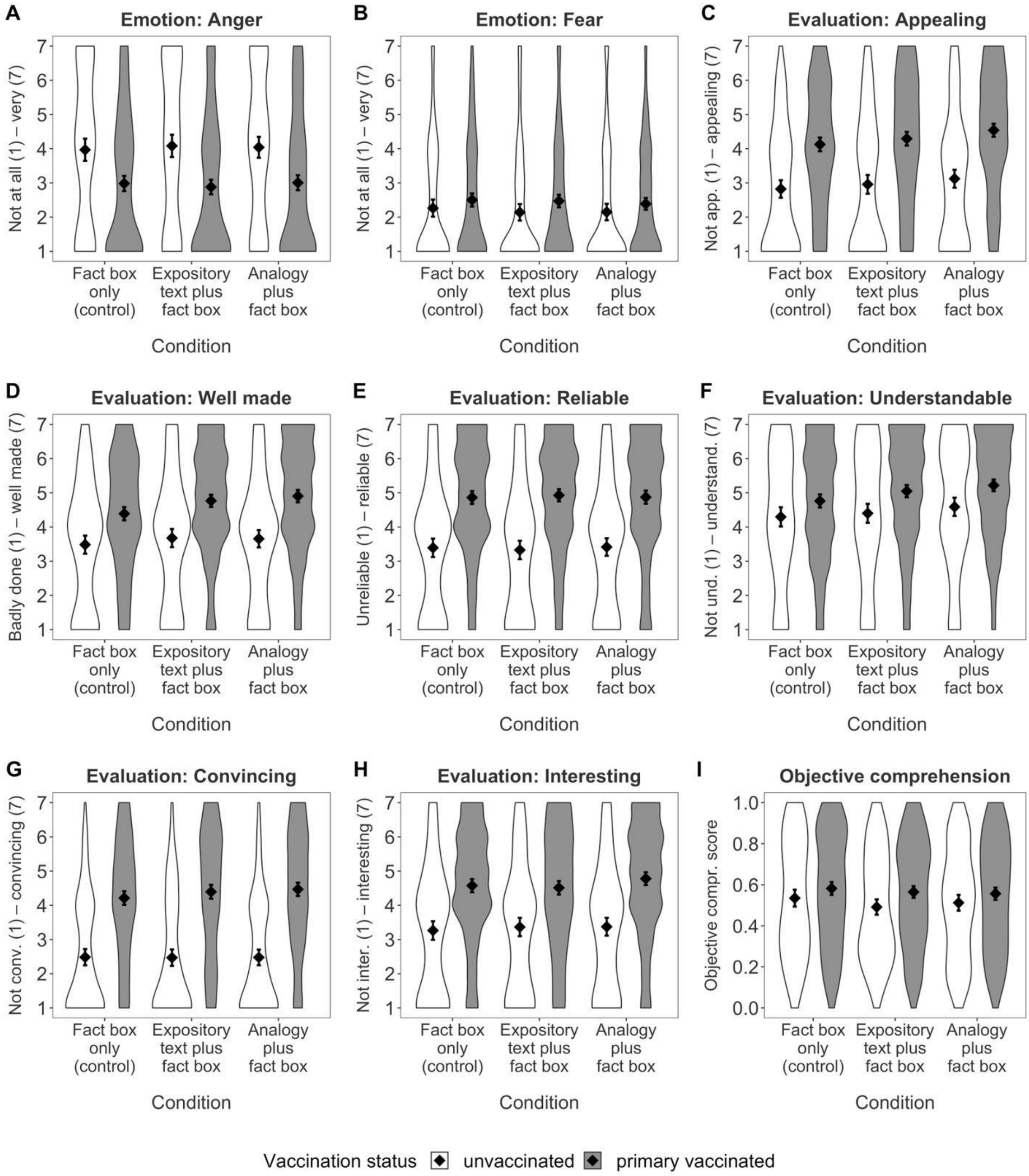

Figure 3. Distribution of Explorative Variables Across Conditions and Vaccination Status
Note. The violin plots visualize the density distributions of the responses. The diamond indicates the group mean, and the whiskers represent the bootstrapped 95% confidence interval. Primary vaccinated participants indicated lower anger (A), more fear (B), evaluated the materials better on all six dimensions (C–H), and scored higher on the objective comprehension test (I) than unvaccinated participants. There were no significant interaction effects. The condition analogy plus the fact box was rated as more appealing (C), better made (D), and more understandable (F) than the fact box only condition. The expository text plus fact box condition was rated as better made (D) than the fact box-only condition. Post hoc tests revealed no significant differences between the text conditions.

Explorative Analyses

The perception and comprehensibility of the information material are relevant to how likely potential recipients are inclined to elaborate on them (Petty & Cacioppo, 1986; Trevors, 2022). Thus, we explored the emotions of anger and fear, the evaluation of the presented information material, and the objective comprehension of the Covid-19 vaccine's benefits and risks depending on the condition and vaccination status. Two-factorial ANOVAs explored elicited emotions, subjective evaluation, and objective comprehension of the different materials (all means and ANOVAs are reported in Supplement S5). Figure 3 shows that unvaccinated participants consistently evaluated the materials more negatively.

Evaluation of the Materials. The level of anger and fear, which indicate potential reactance (Brehm, 1966), was similarly low across the three conditions (*F*s < 0.59). Unvaccinated participants reported being more annoyed and less frightened when reading the material than primary vaccinated participants (anger: $F(1, 1{,}542) = 95.94$, $p < .001$, $\eta^2 = .06$, $d = 0.58$; fear: $F(1, 1{,}542) = 9.24$, $p = .002$, $\eta^2 < .01$, $d = -0.18$; no significant interactions *F*s < 0.37). They also rated the information material as less positive on all six dimensions than primary vaccinated participants (*F*s < 415.79; no significant interactions *F*s < 0.17). The smallest effect of vaccination status was on the dimension 'understandable' $F(1, 1{,}542) = 39.58$, $p < .001$, $\eta_p^2 = .03$, $d = -0.37$). In general, the analogy condition received significantly higher ratings than the control condition on the evaluation dimensions 'appealing' ($F(2, 1{,}542) = 5.45$, $p = .004$, $\eta_p^2 < .01$, post hoc test $p = .003$, $d = -0.20$), 'well made' ($F(2, 1{,}542) = 7.24$, $p < .001$, $\eta_p^2 < .01$, post hoc test $p = .001$, $d = -0.22$), and 'understandable' ($F(2, 1{,}542) = 6.56$, $p = .001$, $\eta_p^2 < .01$, post hoc test $p < .001$, $d = -0.23$). The evaluation of the expository text exceeded the ratings of the control condition only regarding the dimension 'well made' (post hoc test $p = .010$, $d = -0.18$).

Objective Comprehension of the Information Material. The objective comprehension scores did not significantly differ between the conditions ($F(2, 1{,}540) = 1.47$, $p = .230$, $\eta_p^2 < .01$; all means are reported in Supplement S5). Primary vaccinated participants ($M = 0.6$, $SD = 0.3$, $n = 975$) scored slightly higher on the objective comprehension test than did unvaccinated participants ($M = 0.5$, $SD = 0.3$, $n = 573$, $F(1, 1{,}540) = 14.75$, $p < .001$, $\eta_p^2 < .01$, $d = -0.22$; no significant interaction $F < 0.43$).

Discussion

In theory, explaining why vaccination is an effective response strategy should help unvaccinated and primary vaccinated people make an informed decision (Davis et al., 2022; Ort & Fahr, 2018). This should be especially relevant for hesitant people who are often concerned about vaccine effectiveness and safety (Lin et al., 2020; Wang et al., 2021). Our study tested whether different ways of explaining the vaccine mechanism influence vaccine perceptions and intentions. Fact boxes displaying vaccine benefits and adverse events were supplemented with explanatory texts, one of which used an analogy to relate medical knowledge to everyday knowledge. Explaining how the mRNA vaccine protects people increased the perceived vaccine effectiveness of preventing Covid-19 compared to presenting only the evidence-based numbers on vaccine effectiveness in a fact box (H1). The absence of an interaction with vaccination status may suggest that the intervention could be similarly effective for more hesitant (unvaccinated) participants and less hesitant (primary vaccinated) participants. From a theoretical perspective, response efficacy is an important determinant for intention or actual behaviour in many health behaviour theories, like the PMT. Messages about vaccine effectiveness (i.e., response efficacy in terms of the PMT) often state that vaccination effectively reduces the risk of contracting the disease and its severity, even using actual numbers on the vaccine's effectiveness (Davis et al., 2022; Lu et al., 2023). The study's results suggest that, beyond this, adding information about the vaccine's mechanism to a public health information intervention could increase perceived response efficacy. Since factually describing a vaccine's mechanism is neutral information, this component could be of interest when aiming to design information for an informed vaccination decision without using persuasion techniques. Nevertheless, these findings are conditioned to mRNA vaccination technology and the context of the Covid-19 pandemic. Further research should attempt to replicate these findings for other vaccination technologies than mRNA vaccines and test if explaining the vaccine mechanism only contributes to the perception of response efficacy in the case of low prior knowledge about the technology (e.g., for new inventions).

Although the effect of explaining the vaccine mechanism was only small, it is remarkable that an educational text at the end of the alert phase in the SARS-CoV2-pandemic can still influence vaccine beliefs. Even a very small effect can be of practical relevance if a low-cost intervention is rolled out at a large scale (Götz et al., 2022), such as disseminating a text to the public. This is important since beliefs about the response efficacy are an important determinant of the attitude toward vaccination (Ort & Fahr, 2018). That the educational texts only affected the perceived vaccine effectiveness of preventing Covid-19 but not the perceived vaccine effectiveness of preventing severe Covid-19 (see Supplement S2 for results) demonstrates that the educational text works best for the vaccine outcome it explicitly addresses. This implies that health communicators should explicitly incorporate the message into the material (Blalock & Reyna, 2016; Broniatowski et al., 2016; Reyna et al., 2021).

Presenting the information as an analogy did not increase the perceived vaccine effectiveness compared to an expository text. One potential reason is that if the explained health concept is easy to understand, there is no need to facilitate comprehension through an analogy (Galesic & Garcia-Retamero, 2013). In line with this explanation, both texts received similar scores for subjective understandability and objective comprehension. Another potential reason is that analogies are less effective if the reader holds a strong attitude about the source or target domain (Semino, 2021; Thibodeau et al., 2019). However, the lack of an interaction effect between condition and vaccination status could indicate that this explanation may not apply to our study. The analogy and expository text led to similar effectiveness perceptions in unvaccinated participants with more negative pre-existing attitudes toward Covid-19 vaccination. The same was true for primary vaccinated participants with more moderate pre-existing beliefs. For further discussions of the chosen analogy, see Supplement S6.

In line with previous studies, a higher perceived vaccine effectiveness was associated with a lower perceived risk of vaccination (Mostafapour et al., 2019). Nevertheless, informing about personal benefits through the vaccine's protection did not directly lower perceived vaccine risks (H2). Unvaccinated people–but also non-boosted people–hold negative attitudes and beliefs toward Covid-19 vaccines (Sprengholz et al., 2023). Those pre-existing beliefs about vaccine safety seem quite firm after the first Covid-19 vaccine was made available two and a half years ago. In this case, directly addressing these safety concerns might be promising.

Comparing the coronavirus with a bank robber and the Covid-19 vaccination with the messenger of a 'Wanted' picture did not increase the intention to get vaccinated against Covid-19 (H3). The analogy was supposed to strengthen the perception of the response strategy by drawing attention, visualizing the abstract concept of the vaccine mechanism, and facilitating comprehension, thus leading to a greater intention than an expository text or only a fact box (Duit, 1991; Feng et al., 2013; Woolley, 2010). Our explorative results of the subjective material evaluation suggest that the supposed benefits of an analogy were only partially present in comparison to the fact box-only condition and not at all in comparison to the expository text. Further, the objective comprehension of the vaccine's benefits and risks was the same, regardless of whether participants only saw the fact box, an expository text, or the analogy. In line with our results, Ervas et al. (Ervas et al., 2022) found no effect of explaining herd immunity through Covid-19 vaccination as a collective endeavour similar to 'bees in a beehive' on vaccination intention. Moreover, previous research on educational interventions communicating about Covid-19 vaccine development and safety did not find an effect on intention (Thorpe et al., 2022). In one study, viewing an animated YouTube video explaining how Covid-19 mRNA vaccines work increased vaccination intention, but reading the same information in a script did not (Witus & Larson, 2022). In contrast to these results, a study using analogies to emphasize the disease threat by framing the flu virus as, for example, a beast reported a positive influence on intention (Scherer et al., 2015). These results indicate that educational interventions may integrate persuasive interventions when aiming to change pre-existing beliefs and intentions on short notice.

Overall, the vaccination status (i.e., the self-reported past vaccination decision) was highly relevant to the response behaviour. For example, unvaccinated participants rated the vaccine's effectiveness in preventing (severe) Covid-19 as lower than participants with primary vaccination did. They also perceived the mRNA vaccine as riskier and were less inclined to get vaccinated against Covid-19. Concerning the PMT, these results suggest that unvaccinated participants view the Covid-19 vaccination as a less promising response strategy and have a lower vaccination motivation than participants with primary vaccination. In our study, the vaccination status attenuated the underlying factors forming the vaccine beliefs. Other research has shown that unvaccinated individuals are less confident in the Covid-19 vaccine, more concerned about vaccination risks, and hold more misconceptions about Covid-19 and the vaccine (Kricorian et al., 2022; Sprengholz et al., 2023). These pre-existing beliefs can affect how vaccine information is perceived and how ready the individuals update their corresponding beliefs. For example, while providing facts can correct false beliefs (such as misconceptions about Covid-19 mRNA vaccines' effectiveness and safety), previously held beliefs can still influence people's thinking (continued influence effect) (Ecker et al., 2022). Furthermore, people tend to discount information when they do not support their pre-existing (strong) beliefs (confirmation bias) (Malthouse, 2023). As the tested material was likely not in line with unvaccinated individuals' pre-existing beliefs about the response efficacy, it is plausible that they evaluated the information material as worse, were more annoyed by the materials regardless of the assigned condition, and more often answered the comprehension questions incorrectly. When focusing on individuals with primary vaccination, a peculiar factor is that their actual (positive and negative) vaccination experiences influence beliefs about the Covid-19 vaccines as a response strategy. In general, past behaviour is a powerful determinant of future behaviour as it influences decision-making through conscious and non-conscious cognitive processes (Albarracín & Wyer, 2000; Hagger et al., 2018). Thus, when designing educational interventions to increase vaccination intention, the drivers and cognitive processes forming vaccine beliefs of those target groups should be considered. In this context, explaining the vaccine mechanism might address misconceptions, especially held by unvaccinated individuals, and reinforce positive vaccine beliefs by validating past vaccination behaviour of individuals with primary vaccination. Nevertheless, a more tailored approach should address specific concerns, misconceptions, and negative vaccination experiences to increase the vaccination intentions of unvaccinated and primary vaccinated individuals.

Limitations

The chosen analogy, the sampling date, and the control condition limit the conclusions that can be drawn from this study's findings. First, the perception of an analogy depends on the chosen source domain, the cultural background of the recipient, and how suitable it is for describing the target domain (Brugman et al., 2022). We deliberately chose bank robbery as the source domain because it is a well-known concept in Germany, and the 'Wanted' picture analogy has been used in popular science literature before to describe the mechanism of vaccines (Coffee & Perkins, 2021). The evaluation of the information materials suggests that the analogy was understandable but only moderately interesting. Regardless, the results must be interpreted by considering this specific analogy. Further research could test whether other source domains, such as orchestras or sports competitions, may be more interesting for German recipients. Since analogies are more effective when there are no firm pre-existing beliefs, using an analogy for vaccination should be tested with diseases and vaccines that are less emotionally debated than Covid-19. Furthermore, a more narrative approach to explaining the vaccine mechanism could make the text more interesting and thus increase the elaboration on vaccines as an effective response strategy.

Second, the study was conducted in the third year of the SARS-CoV2 pandemic. The media had widely covered the progress of the pandemic and news about the different Covid-19 vaccines. By then, most German citizens able and willing to vaccinate had already been fully vaccinated. Thus, in an earlier stage of the pandemic, when the mRNA vaccine was still a newer concept, explaining the personal benefit in an expository text or as an analogy might have had a greater impact on the vaccine's perceptions or even the vaccination intention. Nevertheless, the current study still found a small effect of explaining the mRNA vaccine mechanism on perceived vaccine effectiveness, despite being conducted in the late phase of the pandemic. In the case of introducing a new vaccine technology, greater effect sizes and differentiated effects between text types may be expected.

Third, the experimental design did not employ a strong control condition without any information. Instead, participants in the control condition received a fact box containing the benefit-risk profile of the mRNA vaccine. The advantage of this approach was that all participants were equally able to make informed health decisions using the presented information. However, the type of control condition must be considered when interpreting the results and effect sizes. Future studies adapting a no-information-control condition could expect greater effect sizes by presenting expository texts or analogies only.

Finally, conducting multiple explorative tests increased the chance for alpha error accumulation and overinterpreting results when only relying on the reported *p*-values. When interpreting results, focusing on the reported effect sizes (in the study's case, Cohen's *d*) facilitates a more comprehensive understanding of the research findings (Lakens, 2022). In contrast to *p*-values, effect sizes provide information about the magnitude of an effect, regardless of the sample size. Thus, it was reported for all conducted analyses, regardless of whether the p-value signalled the presence or absence of an effect. The interpretation and discussion of the study's results focused on the preregistered analyses and results with substantial effect sizes. Beyond this, explorative small effects were drawn on to discuss possible explanations.

Conclusion

Even after the large-scale rollout of Covid-19 vaccines and extensive data on their effectiveness and safety, concerns among laypeople persist. Explaining underlying effect mechanisms—that is, the how—may help elaborate on the personal benefits from an effective vaccine—that is, the what. In our study, explaining the mRNA vaccine mechanism in addition to evidence-based numbers on vaccine efficacy, lead to a higher perceived vaccine effectiveness (small effect) and thus more positive beliefs about vaccines as a response strategy. Thus, elaborating on the vaccine mechanism may contribute to an informed vaccination decision.

Notes

1. Data collection occurred in two waves due to an error in displaying the fact box. During the first wave, one participant noted that the picture was broken. A single-choice question was added to ask whether the participant saw the fact box. Data analyses only included participants who confirmed seeing the fact box (first wave: $n = 910$). One participant indicated receiving three vaccine doses at the end of the survey and was excluded. In a second wave, additional 639 participants were recruited to reach the preregistered sample size. In total, 1,548 of 2,187 participants with complete data sets met the preregistered inclusion criteria and indicated to have seen the fact box.
2. The comprehension questions were pretested with a fictitious disease and adapted to the Covid-19 information material. One comprehension question had missing values for two participants due to a programming error. Thus, the objective comprehension score was calculated for $n = 1{,}546$ participants.

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Supplementary Material

The supplementary material can be accessed here: https://doi.org/10.47368/ejhc.2024.102.

Ethical Approval

The research obtained ethical clearance from the University IRB of Erfurt (approval number: 20221122).

Conflict of Interest

The authors declare that they have no conflict of interest.

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