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Debunking Misinformation and Communicating Critical Events in Vaccine Trials

Experimental Evidence on Vaccination Intentions in SARS-CoV-2 Pandemic

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Abstract

Misinformation and media reports about critical events in vaccine trials challenge public confidence in Covid-19 vaccine safety. Three online experiments using 2×2 between-subjects designs examined the impact of vaccine type, misinformation debunking, and critical events during vaccine trials. In Experiment 1, $N = 984$ participants received information about different vaccines and misinformation was debunked. In Experiment 2, $N = 1{,}018$ participants were informed about different vaccines and trial discontinuation. In Experiment 3, $N = 1{,}006$ participants received information about discontinuation and questionable research practices of a manufacturer. The main dependent variables were confidence in vaccine safety, vaccination intention, and willingness to participate in a vaccine trial. Debunking increased vaccination intention and confidence (both $\eta_p^2 = .01$) which was partly higher for classical than

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for new vaccines (η_p^2 = .01). Information about discontinuation had no effect, but having heard about it before had benefits. Information about questionable research practices decreased confidence ($\eta_p^2 = .01$) and vaccination intention ($\eta_p^2 = .02$) regarding the target vaccine but did not affect other vaccines. Confidence (β = .47) was most strongly associated with willingness to participate in vaccine trials. Critical events in vaccine trials should be communicated transparently to increase confidence, trial participation, and vaccination intentions.

Keywords

Vaccine confidence, vaccination intention, willingness to participate in a vaccine trial, misinformation, debunking.

In September 2020, the British pharmaceutical company AstraZeneca paused its clinical Covid-19 vaccine trials after a participant developed an unexplained illness (AstraZeneca, 2020a). A few weeks later, the media reported dosing and communication errors in AstraZeneca's vaccine trials. In particular, in November 2020, AstraZeneca reported a 70% efficacy for their Covid-19 vaccine (AstraZeneca, 2020b). According to media reports, they added the results of two studies, although each used different amounts of the vaccine. The company initially stated to the press that the differences in dosing over different studies were intentional. In fact, however, giving a half-dose in one of the studies was apparently a manufacturing error. Instead of excluding participants with the lower dose from the study, the study design was adjusted when the error was discovered ("Kritik an Impfstudie [criticism on vaccine trial]," 2020; Robbins & Mueller, 2020; Schöps, 2020; "Wie wirksam ist AstraZenecas Impfstoff wirklich [How effective is AstraZeneca's vaccine really]," 2020). Such media reports about critical events in vaccine trials, regardless of their actual veracity, could affect vaccination intentions. Also, people may be unwilling to participate in a vaccine trial themselves or may drop out after hearing information about adverse events or dosing errors in such a trial. Volunteers, however, are urgently needed to advance the approval of vaccines, and the public's vaccination intention is of crucial importance for SARS-CoV-2 pandemic control (WHO, 2020).

However, not all people are eager to get vaccinated. The World Health Organisation (WHO) defines vaccine hesitancy as "the reluctance or refusal to vaccinate despite the availability of vaccines" (para. 27) and put it on the top 10 list of global health threats in 2019 (WHO, 2019). Besides the communication of critical events in vaccine trials, there are other factors that could challenge vaccination intentions. Betsch et al. (2018) identified five psychological antecedents of vaccination (5C): confidence in vaccine safety and efficacy, complacency (reduced risk perception), constraints in everyday life (practical barriers), calculation of vaccination risks and benefits, and collective responsibility. Confidence in vaccine safety may be especially relevant regarding the Covid-19 vaccines (Betsch et al., 2021a) because they are mainly new vaccine types that have not been approved before (Hrynick et al., 2020). For example, in addition to classical inactivated vaccines (e.g., from Novavax), there are also new gene-based vaccines (e.g., from BioNTech/Pfizer) that can be produced quickly and in large quantities, and thus represent a promising solution for combatting the SARS-CoV-2 pandemic.

However, these new vaccines are the subject of critical public debates, and confidence is challenged by misinformation, causing confusion and uncertainty (WHO, n.d.).

Misinformation is "false information that is spread either by mistake or with intent to mislead" (Lewandowsky et al., 2020, p. 4). For example, the scientifically untrue misinformation that the new gene-based Covid-19 vaccines would interfere with the human genome has been a widely circulated message on social media (Reuters Staff, 2020). Evidence suggests that believing such misinformation is associated with decreased vaccination intention (Freeman et al., 2020); this highlights the importance of ensuring that people are correctly informed about Covid-19 vaccination to avoid negative consequences of misinformation. One way to correct circulating misinformation is to debunk it (Lewandowsky et al., 2020). Debunking means "presenting a corrective message that establishes that the prior message was misinformation" (Chan et al., 2017, p. 1532) and is often used for risk communication related to vaccination (Vivion et al., 2020). To effectively debunk misinformation, clear information should be provided, explaining why misinformation is false and what is true instead (Lewandowsky et al., 2020).

The present study explored the impact of different vaccine types, misinformation debunking, and critical events in vaccine trials on confidence in vaccine safety, vaccination intention, and willingness to participate in a vaccine trial, among other outcomes.

Overview: Experiments 1–3

Three online experiments were conducted between September and December 2020 to assess how the German population evaluated different Covid-19 vaccine types and how confidence in vaccine safety and vaccination intention could be increased through debunking vaccine-related misinformation. Furthermore, the impact of communicating critical events in vaccine trials, such as trial discontinuation and questionable research practices, on confidence, vaccination intention, trust in science, and willingness to participate in a vaccine trial was examined. Moreover, individual differences in the willingness to participate in a vaccine trial were explored and how these are related to confidence in the safety of vaccines, trust in science, and other variables.

At the time when the first and second experiments were conducted, no vaccine had yet been approved on the European market. In Russia, there was an emergency approval for the vector-based vaccine Sputnik V. The media in Germany had generally not yet reported much on vaccines. However, the topic of vaccination was discussed on social media and a lot of misinformation circulated on these platforms (Singh et al., 2020). At the time of the third experiment, there was another emergency approval in the UK (BioNTech/Pfizer), but still no vaccine had been approved on the German market. However, the German media increasingly reported on the development of vaccines and critical events in vaccine trials. The German population increasingly followed medical progress via the media (Betsch et al., 2020b; Betsch et al., 2020c).

Transparency and Openness

All data, the analysis code, research materials, and questionnaires are available at https://osf.io/hrdw8/. The materials and questionnaires are also in the appendix. The data were analysed using IBM SPSS Statistics, version 27. Experiments 1 and 2 were exploratory and not preregistered. For Experiment 3, the study's design, hypotheses, and analysis plans were preregistered at https://aspredicted.org/3s429.pdf.

Experiment 1

In the first experiment, the influence of explaining the functionality of two different Covid-19 vaccine types on confidence in vaccine safety and vaccination intention was explored. A classical inactivated vaccine was compared with a new gene-based vaccine because the Covid-19 vaccines are based on this technology. People may have more confidence in the safety of inactivated/dead vaccine types (Betsch et al., 2021b) that have been used in practice for many years (e.g., against diphtheria). In contrast, gene-based vaccines have never been approved before. As it is difficult to build trust (Levi, 1998), especially at an early stage (Wang & Huff, 2007) and in times when misinformation is widespread in social media (Gallotti et al., 2020), there could be differences in confidence related to the vaccine type. Furthermore, confidence is associated with vaccination intention (Betsch et al., 2018) that could thus also differ between the two vaccine types.

In addition, the effect of debunking misinformation associated with a particular vaccine type on confidence and vaccination intention was explored, as debunking is a recommended strategy to combat misinformation (Lewandowsky et al., 2020). The research questions were:

RQ1: What is the impact of vaccine type on confidence in vaccine safety and vaccination intention?

RQ2: What is the impact of misinformation debunking on confidence in vaccine safety and vaccination intention?

Methods

Study Design and Participants. The online experiment was a 2 (vaccine type: classical [inactivated] vs. new [gene-based]) × 2 (debunking: yes vs. no) factorial between-subjects design. It was conducted as part of the German cross-sectional Covid-19 Snapshot Monitoring (COSMO) study series (Betsch, Wieler, et al., 2020) on September 1–2, 2020. The participants could only take part in one of the surveys. They were automatically, randomly, and equally allocated to the four conditions via the online software Unipark by Questback and were not aware of the condition assignments. The sample was a German nonprobabilistic quota sample representing the adult general population aged 18–74 years for age and gender (crossed) and federal state (not crossed) based on census data from Germany. The study participants were invited and financially compensated by the market research institute Respondi. No attention controls were used and no participants were removed from the sample. The study received ethical approval from the institutional review board at the University of Erfurt (#20200302/20200501).

Interventions, Outcomes, and Procedure. The participants received a link to the online questionnaire and provided informed consent prior to participation. They first provided demographic information and answered the COSMO survey questions (https://projekte.uni-erfurt.de/cosmo2020/web/). This was followed by the experiment (see Appendix A for material and questionnaire). The participants were asked to imagine that there is already a vaccine against Covid-19 in the German market recommended for them. They were told about either an inactivated or a gene-based vaccine that effectively protects against Covid-19. The most common side effects of the vaccines were mentioned, and it was explained how the respective vaccine works.

Half of the participants who were informed about the inactivated vaccine and half of the

participants who were informed about the gene-based vaccine also received a debunking of an instance of widespread misinformation related to the vaccine. The strategy of debunking was chosen because widespread misinformation can cause great damage, and a fact-based correction seems promising to change false beliefs (Lewandowsky et al., 2020). Following the debunking handbook, after reading about facts on the vaccine and about the misinformation, the participants read a short explanation of why the information is wrong and what is true instead (Lewandowsky et al., 2020). Regarding the gene-based vaccine, the misinformation that the vaccine will interfere with the human genome (German Federal Ministry of Health, 2022; Reuters Staff, 2020) was debunked. The participants read the following text:

> "Some people fear that gene-based vaccination will interfere with the human genome. However, it is impossible for the viral RNA to enter the human cell nucleus, where the human genetic material is located on the chromosomes. The material of an RNA vaccination can therefore not interfere with the human genome."

Regarding the inactivated vaccine, the misinformation that the vaccination could cause the disease (Robert Koch Institute, 2016) was debunked. The participants read the following text:

> "Some people fear that vaccination could cause the disease. However, it is impossible for the inactivated pathogens to reproduce. Therefore, an inactivated vaccination cannot cause a disease."

After reading the scenario and information, the participants were asked to assess the vaccine. Because of space limitations, single items were used. Confidence was measured using the item from the 5C short scale (7-point scale from 1 = *strongly disagree* to 7 = *strongly agree*; Betsch et al., 2018) adapted for Covid-19. This was followed by the assessment of vaccination intention for the particular vaccine (7-point scale from 1 = *not at all getting vaccinated* to 7 = *definitely getting vaccinated*). The design did not require manipulation checks.

Statistical Methods. Two-way ANOVAs were conducted to compare the groups for confidence and vaccination intention. An alpha of 5% was accepted as the significance level. A statistical a priori power analysis for a two-way ANOVA was conducted using G*Power to estimate the sample size. Thus, a sample size of N = 788 would have been sufficient to detect small main effects (Cohen's f = .10) with a power of .80. Because the sample size for the COSMO study series is always approximately N = 1,000, the sample size was sufficient.

Results

Study Population. Of the 1,067 eligible participants invited to participate, 988 (92.6%) fully completed the study. The exclusion of four individuals who had already participated in one of the previous COSMO surveys resulted in a final sample of N = 984 participants (M_{age} = 46.5, SD_{age} = 15.8; 47.7% female) that were included for data analysis (n_1 = 245 [classical vaccine type, no debunking]; n_2 = 245 [classical vaccine type, debunking]; n_3 = 247 [new vaccine type, no debunking]; n_4 = 247 [new vaccine type, debunking]).

Confidence in Vaccine Safety. The participants' mean confidence was M = 4.4, SD = 1.9 (28.7% (rather) not confident [1-3], 19.8% undecided [4], 51.5% (rather) confident [5-7]). The results are shown in Figure 1A. The participants who were told about the classical vaccine type had a higher confidence in the vaccine's safety than those who were told about the new vaccine

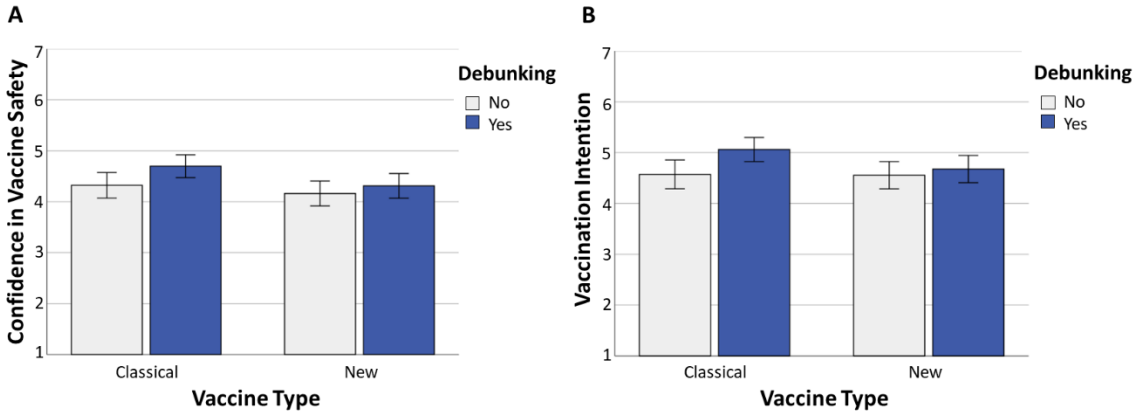

Figure 1. Means for Confidence and Vaccination Intention

Note. N = 984. The figure shows the results from the two-way ANOVAs of the first experiment. The *y*-axes represent the means for confidence in vaccine safety (A) and vaccination intention (B), each on a scale from 1–7. The *x*- axes represent the first experimental factor, and the colours represent the second experimental factor. Debunking significantly increased confidence (A) and vaccination intention (B). The vaccine type influenced confidence, which was significantly higher for a classical vaccine type (A) but had no significant impact on vaccination intention (B). The error bars represent 95% confidence intervals.

type ($F(1,980) = 5.01$, $p = .026$, $\eta_p^2 = .01$, small effect). The participants who received the debunking had higher confidence in vaccine safety than those who did not ($F(1,980) = 4.62$, $p = .032$, $\eta_p^2 = .01$, small effect). There was no significant interaction effect ($F(1,980) = 0.85$, $p = .356$, $\eta_p^2 < .01$). However, a more nuanced look at those participants who received the misinformation debunking ($n = 492$) revealed that the debunking for the classical vaccine type was somewhat more successful, showing higher means for confidence (classical vaccine type: $M = 4.7$, $SD = 1.8$; new vaccine type: $M = 4.3$, $SD = 1.9$; $t(490) = 2.3$, $p = .022$, $d = 0.21$).

Vaccination Intention. The participants' mean vaccination intention was $M = 4.7$, $SD = 2.1$ (25.1% (rather) not willing to vaccinate [1-3], 16.2% undecided [4], 58.7% (rather) willing to vaccinate [5-7]). The results are shown in Figure 1B. The participants who received the debunking had a higher vaccination intention than those who did not ($F(1,980) = 5.15$, $p = .023$, $\eta_p^2 = .01$, small effect). There was no significant main effect for vaccine type ($F(1,980) = 2.23$, $p = .136$, $\eta_p^2 < .01$) and no significant interaction effect ($F(1,980) = 1.87$, $p = .172$, $\eta_p^2 < .01$). However, a more differentiated consideration of those participants who received the misinformation debunking ($n = 492$) showed that the debunking for the classical vaccine type was slightly more successful, showing higher means for vaccination intention (classical vaccine type: $M = 5.1$, $SD = 1.9$; new vaccine type: $M = 4.7$, $SD = 2.1$; $t(483,35) = 2.12$, $p = .035$, $d = 0.19$).

Discussion

The first experiment showed that vaccination intentions were about the same for a classical inactivated and new gene-based Covid-19 vaccine type. However, confidence in vaccine safety was higher with the classical vaccine type. Because the new Covid-19 vaccines are communicated not only as gene-based but also as vector-based vaccine types (e.g., the vaccine from AstraZeneca), the effect of vaccine type should be re-examined, including for a vector-based vaccine type. Receiving a misinformation debunking led to higher confidence and

vaccination intentions. Moreover, the debunking was also somewhat more successful with the classical vaccine type. Compared to the rather new gene-based vaccine types, classical inactivated vaccines have already been proven to be effective and safe in practice for many years. Debunking misinformation in relation to established vaccine types could thus convince more people, as there is simply more evidence. In addition, the misinformation associated with the inactivated vaccine type ("vaccination could cause the disease") has been circulating for many years (Robert Koch Institute, 2016), and people may have read explanations of why this is a fallacy more frequently in the past, which may have contributed to a repeated and thus more effective debunking (Lewandowsky et al., 2020).

The results highlight the importance of correcting misinformation, especially in times of a pandemic when even small effects may make a huge difference in vaccine uptake. Of course, it would be even better if misinformation did not arise at all. To prevent the emergence and spread of false and misleading information, and to avoid the need for debunking interventions, it is important that information about vaccines is communicated honestly and transparently. However, this is a particular challenge in times of the SARS-CoV-2 pandemic, when numerous new vaccines are being tested in vaccine trials and where critical events such as adverse reactions and media reports on dosing and communication errors may occur more frequently, damaging confidence in vaccine safety and vaccination intentions. The impact of communicating such events will therefore be examined in the second and third experiment.

Experiment 2

The second online experiment re-examined the impact of different vaccine types on confidence in vaccine safety and vaccination intention. This time, two classical vaccine types (inactivated and attenuated) were compared with two new vaccine types (gene-based and vector-based). Vector-based vaccines are also gene-based, but because the public refers to vector-based and gene-based mRNA vaccines, these formulations were used. In addition, the impact of communicating a vaccine trial discontinuation because of an unexplained illness in a participant will be examined, which is what occurred in a vaccine trial in September 2020 (AstraZeneca, 2020a). Willingness to participate in a vaccine trial was added as a further dependent variable because this is of particular interest in relation to a vaccine trial discontinuation. The research questions were:

> *RQ1:* What is the impact of vaccine type on confidence in vaccine safety, vaccination intention, and willingness to participate in a vaccine trial?
>
> *RQ2:* What is the impact of vaccine trial discontinuation on confidence in vaccine safety, vaccination intention, and willingness to participate in a vaccine trial?

Methods

Study Design and Participants. The online experiment was a 2 (vaccine type: classical [inactivated or attenuated] vs. new [vector-based or gene-based]) × 2 (vaccine trial discontinuation: information vs. no information) factorial between-subjects design. A first screening showed that the groups did not differ between inactivated and attenuated vaccine types, and between vector-based and gene-based types. Therefore, these conditions were combined into "classical" and "new." The experiment was conducted as part of the above-mentioned German cross-sectional COSMO study series on October 27–28, 2020. Details on

randomisation, description of the sample, inclusion of participants, and ethical approval can be found in the Methods section of Experiment 1 because it was identical to that of Experiment 2.

Interventions, Outcomes, and Procedure. The procedure was the same as for Experiment 1 (for details, see the Methods section of Experiment 1). In Experiment 2 (see Appendix B for material and questionnaire), the participants were informed about the numerous vaccine trials underway to test the various Covid-19 vaccines produced using different technologies. Afterwards, half of the participants received information about the discontinuation of a vaccine trial in September 2020 because of an unexplained illness of one participant. All participants were then asked to imagine that the first vaccine was already approved, available, and recommended for them. They were told about either an inactivated, attenuated, vector-based, or gene-based vaccine, and they received an explanation of how the particular vaccine works. The dependent variables were the same as in Experiment 1 (for details, see the Methods section of Experiment 1). Additionally, willingness to participate in a vaccine trial was assessed (single choice, *yes*/*no*/*don't know*), and the participants were asked whether they had heard about the critical event before participating in the current study (single choice, *yes/no*). Moreover, information frequency on the topic of Covid-19 (7-point scale from 1 = *never* to 7 = *very often*) was assessed before the experiment as part of the survey. The design did not require manipulation checks.

Statistical Methods. Two-way ANOVAs were conducted to compare the groups for confidence and vaccination intention, here using the experimental factors for one analysis and real-world knowledge about discontinuation as a factor in a further analysis. A binary logistic regression analysis was conducted to explore individual differences in the willingness to participate in a vaccine trial. Therefore, the variable was recoded into a dichotomous variable (*no* vs. *yes*; participants who indicated *don't know* were coded as *no*). Moreover, in a further exploratory analysis, an unpaired t-test was conducted to examine the differences in information frequency (a variable regularly assessed in the COSMO survey) for participants who already knew and did not know about vaccine trial discontinuation prior to the study. An alpha of 5% was accepted as the significance level. A statistical a priori power analysis for a two-way ANOVA was conducted using G*Power to estimate the sample size. Thus, a sample size of $N = 788$ would have been sufficient to detect small main effects (Cohen's $f = .10$) with a power of .80. Because the sample size for the COSMO study series is always approximately $N = 1{,}000$, the sample size was sufficient.

Results

Study Population. Of the 1,190 eligible participants who were invited to participate, 1,022 (85.9%) fully completed the study. The exclusion of four individuals who had already participated in one of the previous COSMO surveys resulted in a final sample of $N = 1{,}018$ participants ($M_{age} = 45.4$, $SD_{age} = 15.9$; 50.9% female) being included in the data analysis ($n_1 = 254$ [classical vaccine type, information about vaccine trial discontinuation]; $n_2 = 253$ [classical vaccine type, no information about vaccine trial discontinuation]; $n_3 = 255$ [new vaccine type, information about vaccine trial discontinuation]; $n_4 = 256$ [new vaccine type, no information about vaccine trial discontinuation]). Regarding knowledge about the vaccine trial discontinuation, 43.7% had heard about it, and 56.3% had not heard about it prior to participating.

Confidence in Vaccine Safety. The participants' mean confidence was $M = 4.1$, $SD = 2.0$ (35.9% (rather) not confident [1-3], 20.0% undecided [4], 44.1% (rather) confident [5-7]). The participants who were told about a classical vaccine type had higher confidence if they did not receive information about discontinuation (mean difference (MD) = 0.4, $SD = 0.2$, $p = .012$, $\eta_p^2 = .01$), while the participants who were told about a new vaccine type had similar confidence whether or not they received information about discontinuation (MD = -0.1, $SD = 0.2$, $p = .736$, $\eta_p^2 < .01$; interaction effect $F(1,1014) = 4.06$, $p = .044$, $\eta_p^2 < .01$). However, these effects were small, and there were no significant main effects for vaccine type ($F(1,1014) = 0.70$, $p = .404$, $\eta_p^2 < .01$) and information about discontinuation ($F(1,1014) = 2.37$, $p = .124$, $\eta_p^2 < .01$). The results remained stable when knowledge about discontinuation was included as a covariate.

Because vaccine trial discontinuation is a real-world issue, the participants may have heard about it before participating. To examine the effect of real-world knowledge on confidence, another two-way ANOVA was conducted using vaccine type and knowledge about discontinuation as factors. The results are shown in Figure 2A. The participants who knew about the vaccine trial discontinuation had higher confidence than those who did not ($F(1,1014) = 21.78$, $p < .001$, $\eta_p^2 = .02$, small effect). There was no significant main effect for vaccine type ($F(1,1014) = 0.77$, $p = .380$, $\eta_p^2 < .01$) and no significant interaction between the two factors ($F(1,1014) = 2.98$, $p = .084$, $\eta_p^2 < .01$).

Vaccination Intention. The participants' mean vaccination intention was $M = 4.3$, $SD = 2.2$ (33.1% (rather) not willing to vaccinate [1-3], 17.9% undecided [4], 49.0% (rather) willing to vaccinate [5-7]). There were no significant main effects for vaccine type ($F(1,1014) = 0.32$, $p = .572$, $\eta_p^2 < .01$) and information about discontinuation ($F(1,1014) = 2.24$, $p = .135$, $\eta_p^2 < .01$), along with no significant interaction between the two factors ($F(1,1014) = 1.13$, $p = .288$, $\eta_p^2 < .01$). The results remained stable when knowledge about discontinuation was included as a covariate.

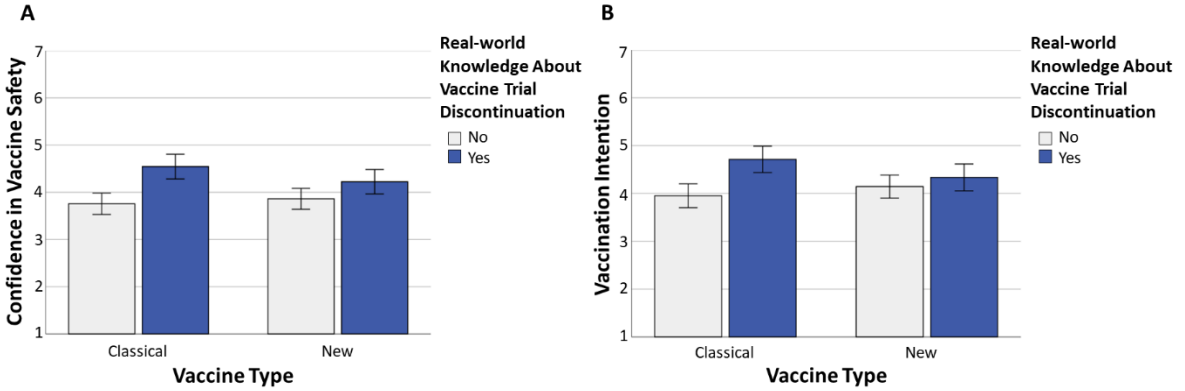

Figure 2. Means for Confidence and Vaccination Intention

Note. N = 1,018. The figure shows the results from selected two-way ANOVAs from the second experiment. The *y*-axes represent the means for confidence (A) and vaccination intention (B), each on a scale from 1–7. The *x*-axes represent the experimental factor 'vaccine type,' and the colours represent the second explorative factor 'real-world knowledge about vaccine trial discontinuation.' Knowledge about a vaccine trial discontinuation had benefits, such as higher confidence (A) and higher vaccination intention, especially for classical vaccine types (B). The error bars represent 95% confidence intervals.

Table 1. Binary Logistic Regression for Willingness to Participate in a Vaccine Trial

Variable	*b*	*SE*	Wald	*df*	*p*	*OR*	95% CI
Constant	-4.53	.36	160.89	1	<.001	.01	
Confidence in vaccine safety	**.65**	**.06**	**115.96**	**1**	**<.001**	**1.91**	**[1.70, 2.15]**
Vaccine type[a]	-.12	.18	.43	1	.511	.89	[.63, 1.26]
Vaccine trial discontinuation[b]	.08	.18	.20	1	.655	1.08	[.77, 1.52]
Knowledge discontinuation[c]	.09	.18	.24	1	.623	1.09	[.77, 1.54]
Nagelkerke's R^2	.25						

Note. N = 1,018. Participants who stated that they would not be willing to participate in a vaccine trial (= 0) vs. those who would be willing to participate (= 1). The overall model was statistically significant ($\chi^2(4) = 171.71$, $p < .001$). All correlations between predictors < .70. Confidence in vaccine safety was significantly associated with the willingness to participate in a vaccine trial. CI = confidence interval. Rows in bold represent significance (p < .05). [a] *Classical* = 0, *new* = 1. [b] *No information* = 0, *information* = 1. [c] *No* = 0, *yes* = 1.

Repeating the analysis using vaccine type and real-world knowledge on discontinuation as factors (see Figure 2B) showed that the participants who heard about vaccine trial discontinuation had a higher vaccination intention than those who did not ($F(1,1014) = 12.79$, $p < .001$, $\eta_p^2 = .01$, small effect). Moreover, the participants who were told about a classical vaccine type had a higher vaccination intention if they knew about discontinuation, while the participants who were told about a new vaccine type had similar vaccination intention whether or not they knew about it (interaction effect $F(1,1014) = 4.57$, $p = .033$, $\eta_p^2 < .01$, small effect). There was no significant main effect for vaccine type ($F(1,1014) = 0.49$, $p = .486$, $\eta_p^2 < .01$).

Willingness to Participate in a Vaccine Trial. About one-fifth of the participants (19.2%) would be willing to participate in a vaccine trial. Confidence in vaccine safety, vaccine type, information about vaccine trial discontinuation, and knowledge about vaccine trial discontinuation were included as independent variables in the binary logistic regression analysis. Vaccination intention was not included as it correlated strongly with confidence (> .70). Table 1 displays the results. The overall model was statistically significant ($\chi^2(4) = 171.71$, $p < .001$) with a Nagelkerke's R^2 of .25. Confidence was strongly associated with the willingness to participate in a vaccine trial ($OR = 1.91$, $p < .001$). There were no significant results regarding the other included variables.

Further Analysis. The previous analyses have shown that knowledge of vaccine trial discontinuation was associated with higher confidence and higher vaccination intention. To examine whether this was related to how often someone informs themselves about Covid-19, the variable information frequency was used. The participants' mean information frequency was $M = 5.4$ ($SD = 1.5$). The unpaired t-test revealed that the participants who already knew about the vaccine trial discontinuation also informed themselves more often about Covid-19 in general than those who did not know about it ($t(993.87) = -4.90$, $p < .001$, Hedges' $g = -0.31$, 95% CI[-0.43, -0.18], small to medium effect).

Discussion

The second experiment showed that confidence in vaccine safety and vaccination intention was about the same for the classical and new vaccine types. Thus, the finding of the first experiment that confidence is higher for classical vaccine types could not be replicated. Moreover, information about vaccine trial discontinuation had no impact on confidence and

vaccination intention. Nevertheless, the participants who had already heard about discontinuation prior to participating in the study had higher confidence and vaccination intention and were also more likely to inform themselves about Covid-19 in general. However, this effect of real-world knowledge could not be shown by the experimental factor (information about discontinuation). Therefore, in the third experiment, the effect of discontinuation information will be examined again to gain more clarity. Experiment 2 also showed that the type of vaccine, as well as information and knowledge about discontinuation, did not influence willingness to participate in a vaccine trial; here, willingness to participate increased with higher confidence in vaccine safety.

The trial discontinuation due to adverse reactions was not the only critical event communicated in the context of the Covid-19 vaccine trials. In November 2020, dosing and communication errors in AstraZeneca's vaccine trials were highlighted by the media ("Kritik an Impfstudie [criticism on vaccine trial]", 2020; Robbins & Mueller, 2020; Schöps, 2020; "Wie wirksam ist AstraZenecas Impfstoff wirklich [How effective is AstraZeneca's vaccine really]", 2020). The effect of such information will also be examined in the third experiment.

Experiment 3

The third online experiment re-examined the impact of being informed about a vaccine trial discontinuation, this time by mentioning the relevant pharmaceutical company that was present in the media. In addition, the impact of information about dosing and communication errors in the vaccine trials was examined. Studies from other fields showed that media scandals can have a negative impact on confidence in the affected company and its products (Bozic et al., 2019; Wang & Huff, 2007) and that the loss of trust often extends to other companies and products, as well as to the entire industry (Bozic et al., 2019; Chen, 2008; LeClair, 2019; Wingen et al., 2020). In the case of Covid-19 vaccines, a general loss of trust would be a serious step backward in the fight against the virus.

A key dimension of perceived trustworthiness is integrity (Mayer et al., 1999), which refers, for example, to a company's honesty. Accordingly, reports about questionable research practices and communication errors could have a negative impact on confidence. On the other hand, transparent communication of negative information, such as a trial's discontinuation because of side effects could be an indication of a company's honesty, thus strengthening trust (Jahn & Brühl, 2019). Another study also showed that transparent communication had positive effects on trust and associated behavioural intentions (Auger, 2014), and the second experiment in the current study showed that knowledge of discontinuation may have benefits, such as higher confidence and higher vaccination intentions.

This third experiment examined the impact of information about vaccine trial discontinuation and questionable research practices on confidence and vaccination intention regarding the AstraZeneca vaccine and on other vaccines (such as the vaccines from BioNTech/Pfizer or Moderna). It was also examined how this information affects trust in science in general. In addition, the impact on willingness to participate in a vaccine trial, as well as individual differences in willingness to participate (e.g., confidence in vaccine safety, trust in science), were explored. The main effects for information about questionable research practices and information about discontinuation were hypothesised as follows:

Compared to having received no information,

H1: The level of confidence in the AstraZeneca vaccine (H1a), in other vaccines (H1b), and in science (H1c) will be lower when people have received information about questionable research practices.

H2: Vaccination intention for the AstraZeneca vaccine (H2a) and for other vaccines (H2b) will be lower when people have received information about questionable research practices.

H3: The level of confidence in the AstraZeneca vaccine (H3a), in other vaccines (H3b), and in science (H3c) will be higher when people have received information about vaccine trial discontinuation.

H4: Vaccination intention for the AstraZeneca vaccine (H4a) and for other vaccines (H4b) will be higher when people have received information about vaccine trial discontinuation.

Methods

Study Design and Participants. The online experiment was a 2 (questionable research practices: information vs. no information) × 2 (vaccine trial discontinuation: information vs. no information) factorial between-subjects design. It was conducted as part of the above-mentioned German cross-sectional COSMO study series on December 15–16, 2020. Details on the randomisation, a description of the sample, inclusion of participants, and ethical approval can be found in the Methods section of Experiment 1 because it was identical to that of Experiment 3.

Interventions, Outcomes, and Procedure. The procedure was the same as for Experiments 1 and 2 (for details, see the Methods section of Experiment 1). In Experiment 3 (see Appendix C for material and questionnaire), the participants were informed about the numerous vaccine trials underway to test various Covid-19 vaccines for safety and efficacy. Then, half of the participants received information about the trial discontinuation in September 2020 because of an unexplained illness of one participant. In addition, half of the participants with and without discontinuation information received information about dosing and communication errors in AstraZeneca's vaccine trials. They were for example informed about the results of two vaccine trials being aggregated despite participants in one study being given only half a dose instead of the full vaccine dose. Furthermore, they were informed that AstraZeneca stated that these differences in dosing were intentional although in fact it was a manufacturing error, which was followed by a subsequent adjustment of the study design (see Appendix C for the full material). All the participants were then asked to imagine that the first effective vaccines (including AstraZeneca's vaccine) were approved, available, and recommended for them. The dependent variables were the same as in Experiment 2 (for details, see the Methods sections of Experiments 1 and 2). This time, confidence and vaccination intention were measured for both the Astra Zeneca vaccine and other vaccines, and willingness to participate in a vaccine trial was assessed using a 7-point scale (from 1 = *not at all participating* to 7 = *definitely participating*). Trust in science (a 7-point scale from 1 = *very little trust* to 7 = *very much trust*) was a further dependent variable. Additionally, the participants were asked whether they had heard about the vaccine trial discontinuation or questionable research practices in the media before participating in this study (one item each, single choice, *yes/no*). The design did not require manipulation checks.

Statistical Methods. Two-way ANOVAs were conducted to compare the groups for confidence, trust in science, vaccination intention, and willingness to participate in a vaccine trial. In addition, the influence of real-world knowledge about questionable research practices and discontinuation was explored in another two-way ANOVA. A multiple linear regression was conducted to explore individual differences in the willingness to participate in a vaccine trial. Again, as in Experiment 2, another exploratory two-way ANOVA was conducted to examine the differences in information frequency (a variable regularly assessed in the COSMO survey) for the participants who already knew and did not know about vaccine trial discontinuation and questionable research practices prior to the study. An alpha of 5% was accepted as the significance level. A statistical a priori power analysis for a two-way ANOVA was conducted using G*Power to estimate the sample size. Thus, a sample size of $N = 788$ would have been sufficient to detect small main effects (Cohen's $f = .10$) with a power of .80. Because the sample size for the COSMO study series is always approximately $N = 1{,}000$, the sample size was sufficient.

Results

Study Population. Of the 1,138 eligible participants who were invited to participate in the study, 1,010 (88.8%) fully completed the study. The exclusion of four individuals who had already participated in one of the previous COSMO surveys resulted in a final sample of $N = 1{,}006$ participants ($M_{age} = 45.2$, $SD_{age} = 15.4$; 50.6% female) included for data analysis ($n_1 = 254$ [information about questionable research practices, information about vaccine trial discontinuation]; $n_2 = 252$ [no information about questionable research practices, information about vaccine trial discontinuation]; $n_3 = 249$ [information about questionable research practices, no information about vaccine trial discontinuation]; $n_4 = 251$ [no information about questionable research practices, no information about vaccine trial discontinuation]). Regarding knowledge prior to participating in this study, 33.0% already knew about the vaccine trial discontinuation, and 28.6% already knew about questionable research practices.

Confidence in AstraZeneca Vaccine. The participants' mean confidence in the AstraZeneca vaccine was $M = 3.2$, $SD = 1.8$ (52.8% (rather) not confident [1-3], 23.7% undecided [4], 23.5% (rather) confident [5-7]). The results are shown in Figure 3A. The participants who received the information about questionable research practices had a lower confidence level regarding the AstraZeneca vaccine than those who did not ($F(1,1002) = 14.58$, $p < .001$, $\eta_p^2 = .01$, small effect). Thus, the evidence supports hypothesis H1a. The participants who received information about discontinuation did not differ in their confidence in the vaccine from those who received no information ($F(1,1002) = 2.01$, $p = .156$, $\eta_p^2 < .01$). Thus, there was no evidence for hypothesis H3a. Moreover, there was no significant interaction between the two factors ($F(1,1002) = 0.25$, $p = .617$, $\eta_p^2 < .01$). The results remained stable when knowledge about questionable research practices and knowledge about discontinuation were included as the covariates. Repeating the analysis with real-world knowledge of both issues showed no significant effects.

Confidence in Other Vaccines. The participants' mean confidence in other vaccines was higher compared to the AstraZeneca vaccine ($M = 3.8$, $SD = 1.9$; 40.0% (rather) not confident [1-3], 22.7% undecided [4], 37.3% (rather) confident [5-7]). There were no significant main effects for information about questionable research practices ($F(1,1002) = 0.09$, $p = .767$,

$\eta_p^2 < .01$) and information about vaccine trial discontinuation ($F(1,1002) = 0.98$, $p = .323$, $\eta_p^2 < .01$). Thus, there was no evidence for H1b and H3b. Moreover, there was no significant interaction between the two factors ($F(1,1002) < 0.01$, $p = .957$, $\eta_p^2 < .01$). The results remained stable when knowledge about questionable research practices and about discontinuation were included as the covariates.

Repeating the analysis with real-world knowledge on both issues showed that the participants who did not know about the questionable research practices had higher confidence in other vaccines if they knew about vaccine trial discontinuation ($MD = -0.5$, $SD = 0.2$, $p = .007$, $\eta_p^2 = .01$, small effect), while the participants who knew about questionable research practices had similar confidence in other vaccines, whether or not they knew about discontinuation ($MD = 0.2$, $SD = 0.3$, $p = .452$, $\eta_p^2 < .01$; interaction effect $F(1,1002) = 4.93$, $p = .027$, $\eta_p^2 = .01$, small effect). There were no significant main effects for knowledge about questionable research practices and about discontinuation on confidence in other vaccines.

Trust in Science. The participants' mean trust in science was $M = 4.6$, $SD = 1.7$ (22.5% (rather) not trust [1-3], 18.6% undecided [4], 58.9% (rather) trust [5-7]). There were no significant main effects for information about questionable research practices ($F(1,1002) = 0.45$, $p = .502$, $\eta_p^2 < .01$) and information about vaccine trial discontinuation ($F(1,1002) = 0.12$, $p = .744$, $\eta_p^2 < .01$). Thus, there was no evidence to support hypotheses H1c and H3c. Moreover, there was no significant interaction between the two factors ($F(1,1002) = 0.03$, $p = .855$, $\eta_p^2 < .01$). The results remained stable when knowledge about questionable research practices and knowledge about discontinuation were included as the covariates.

Repeating the analysis with real-world knowledge on both issues showed that the participants who did not know about questionable research practices had higher trust in science if they knew about vaccine trial discontinuation ($MD = -0.6$, $SD = 0.2$, $p = .001$, $\eta_p^2 = .01$, small effect), while the participants who knew about questionable research practices had similar trust in science whether or not they knew about discontinuation ($MD = 0.1$, $SD = 0.2$, $p = .810$, $\eta_p^2 < .01$; interaction effect $F(1,1002) = 4.95$, $p = .026$, $\eta_p^2 = .01$, small effect). There were no significant main effects for knowledge about questionable research practices and about discontinuation.

Vaccination Intention for AstraZeneca Vaccine. The participants' mean vaccination intention for the AstraZeneca vaccine was $M = 3.2$, $SD = 2.0$ (55.1% (rather) not willing to vaccinate [1-3], 19.3% undecided [4], 25.6% (rather) willing to vaccinate [5-7]). The results are shown in Figure 3B. The participants who received the information about questionable research practices had a lower vaccination intention regarding the AstraZeneca vaccine than those who did not ($F(1,1002) = 15.68$, $p < .001$, $\eta_p^2 = .02$, small effect). Thus, the evidence supports H2a. Regarding information about discontinuation, there was no significant main effect ($F(1,1002) = 0.73$, $p = .393$, $\eta_p^2 < .01$). Thus, there was no evidence to support H4a. Moreover, there was no significant interaction between the two factors ($F(1,1002) = 0.65$, $p = .421$, $\eta_p^2 < .01$). The results remained stable when knowledge about discontinuation and about questionable research practices were included as the covariates. Repeating the analysis with real-world knowledge of both issues showed no significant effects.

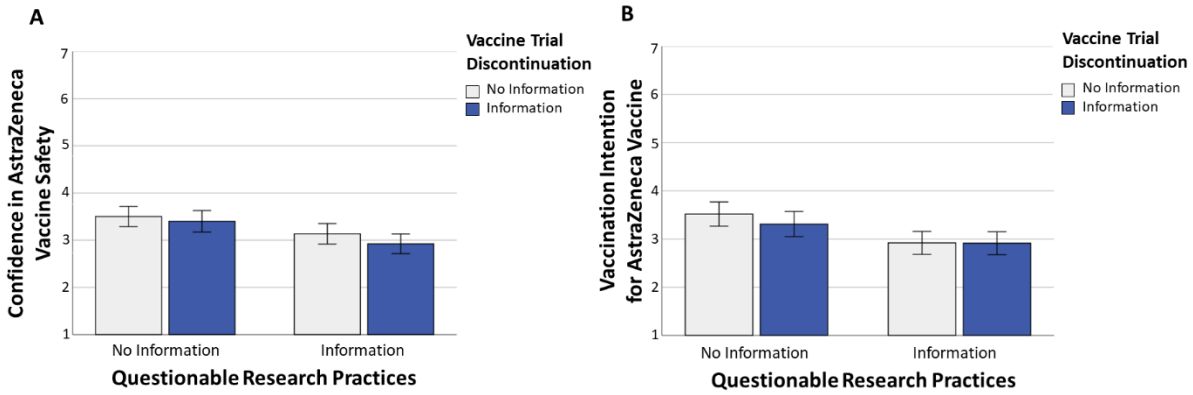

Figure 3. Means for Confidence and Vaccination Intention

Note. N = 1,006. The figure shows the results from selected two-way ANOVAs from the third experiment. The *y*-axes represent the means for confidence (A) and vaccination intention (B) regarding the AstraZeneca vaccine, each on a scale from 1–7. The *x*-axes represent the experimental factor 'information about questionable research practices,' and the colours represent the second experimental factor 'information about vaccine trial discontinuation.' Information about questionable research practices decreased confidence (A) and vaccination intention (B). The error bars represent 95% confidence intervals.

Vaccination Intention for AstraZeneca Vaccine. The participants' mean vaccination intention for the AstraZeneca vaccine was $M = 3.2$, $SD = 2.0$ (55.1% (rather) not willing to vaccinate [1-3], 19.3% undecided [4], 25.6% (rather) willing to vaccinate [5-7]). The results are shown in Figure 3B. The participants who received the information about questionable research practices had a lower vaccination intention regarding the AstraZeneca vaccine than those who did not ($F(1,1002) = 15.68$, $p < .001$, $\eta_p^2 = .02$, small effect). Thus, the evidence supports H2a. Regarding information about discontinuation, there was no significant main effect ($F(1,1002) = 0.73$, $p = .393$, $\eta_p^2 < .01$). Thus, there was no evidence to support H4a. Moreover, there was no significant interaction between the two factors ($F(1,1002) = 0.65$, $p = .421$, $\eta_p^2 < .01$). The results remained stable when knowledge about discontinuation and about questionable research practices were included as the covariates. Repeating the analysis with real-world knowledge of both issues showed no significant effects.

Vaccination Intention for Other Vaccines. The participants' mean vaccination intention for other vaccines was higher compared to the AstraZeneca vaccine ($M = 3.8$, $SD = 2.2$; 42.5% (rather) not willing to vaccinate [1-3], 16.2% undecided [4], 41.3% (rather) willing to vaccinate [5-7]). There were no significant main effects for information about questionable research practices ($F(1,1002) = 0.78$, $p = .378$, $\eta_p^2 < .01$) and information about discontinuation ($F(1,1002) = 1.03$, $p = .311$, $\eta_p^2 < .01$). Thus, there was no evidence for H2b and H4b. Moreover, there was no significant interaction between the two factors ($F(1,1002) < 0.01$, $p = .979$, $\eta_p^2 < .01$). The results remained stable when knowledge about questionable research practices and about discontinuation were included as the covariates.

Repeating the analysis with real-world knowledge on both issues showed that the participants who already knew about discontinuation had a higher vaccination intention ($M = 4.1$, $SD = 2.4$) than those who did not ($M = 3.7$, $SD = 2.1$; $F(1,1002) = 4.04$, $p = .045$, $\eta_p^2 < .01$, small effect). There was no significant main effect for knowledge about questionable research practices and no significant interaction effect for the two factors.

Table 2. Multiple Linear Regression for Willingness to Participate in a Vaccine Trial

Variable	*b*	95% CI	*SE*	ß	*t*	*p*
Constant	.09	[-.64, .82]	.37		.23	.817
Confidence in vaccine safety	**.57**	**[.49, .66]**	**.04**	**.47**	**13.39**	**<.001**
Trust in science	**.11**	**[.03, .20]**	**.04**	**.09**	**2.66**	**.008**
Vaccine trial discontinuation[a]	.14	[-.08, .36]	.11	.03	1.24	.214
Questionable research practices[b]	**.23**	**[.01, .45]**	**.11**	**.06**	**2.08**	**.038**
Knowledge discontinuation[c]	-.14	[-.43, .14]	.14	-.03	-1.00	.318
Knowledge questionable research practices[d]	-.01	[-.30, .28]	.15	.00	-.06	.949
Adjusted R^2	.28					

Note. N = 1,006. Individual differences in willingness to participate in a vaccine trial (1 = *not at all participating,* 7 = *definitely participating*) were explored. The overall model was statistically significant ($F(6,999) = 66.54$, $p < .001$). Confidence in vaccine safety is the mean of confidence in the AstraZeneca vaccine and confidence in other vaccines. All VIFs < 5, and all correlations between predictors < .70. Confidence in vaccine safety, trust in science, and information about questionable research practices were significantly associated with the willingness to participate in a vaccine trial. CI = confidence interval. Rows in bold type represent significance ($p < .05$). [a, b] *No information* = 0, *information* = 1. [c, d] *No* = 0, *yes* = 1.

Willingness to Participate in a Vaccine Trial. The participants' mean willingness to participate in a vaccine trial was $M = 2.9$, $SD = 2.1$ (60.9% (rather) not willing to participate [1-3], 13.8% undecided [4], 25.3% (rather) willing to participate [5-7]). There were no effects of the experimental factors when controlling for real-world knowledge. For the multiple linear regression, confidence in vaccine safety (means of confidence in the AstraZeneca vaccine and other vaccines), trust in science, information about discontinuation, information about questionable research practices, knowledge about discontinuation, and knowledge about questionable research practices were included as independent variables. Vaccination intention was not included as it correlated strongly with confidence (> .70). Table 2 displays the results. The overall model was statistically significant ($F(6, 999) = 66.54$, $p < .001$), with an adjusted R^2 of .28. Confidence in vaccine safety was strongly associated with the willingness to participate in a vaccine trial ($\beta = .47$, $p < .001$). Moreover, trust in science ($\beta = .09$, $p = .008$, small effect), and information about questionable research practices ($\beta = .06$, $p = .038$, small effect) were significantly related to the dependent variable. There were no significant results regarding the other included variables.

Further Analysis. As in Experiment 2, we again assessed whether people who knew about the focal issues searched for information more frequently. The participants' mean information frequency was $M = 5.4$ ($SD = 1.5$). Indeed, the participants who already knew about discontinuation also informed themselves more often about Covid-19 in general ($M = 5.8$, $SD = 1.3$) than those who did not ($M = 5.2$, $SD = 1.5$; $F(1,1002) = 16.78$, $p < .001$, $\eta_p^2 = .02$, small effect). However, this was not true for questionable research practices.

Discussion

The third experiment showed that information about questionable research practices damaged confidence and vaccination intention regarding the target vaccine but did not affect confidence and vaccination intention regarding other vaccines or trust in science in general. Thus, the evidence supported H1a and H2a. The evidence did not support H1b, H1c, H2b, H2c, H3, and

H4. The experiment partially replicated the findings of the second experiment that real-world knowledge about vaccine trial discontinuation may have benefits, such as higher confidence and vaccination intentions, and that participants who knew about it also informed themselves more often about Covid-19 in general. The experiment also showed that information about discontinuation and questionable research practices had no impact on willingness to participate in a vaccine trial. However, willingness to participate in a vaccine trial increased with information about questionable research practices, higher confidence in vaccine safety, and higher trust in science.

General Discussion

The present study examined the influence of explaining the functionality of classical inactivated and new gene-based Covid-19 vaccine types, and debunking misinformation associated with a particular vaccine type, on confidence in vaccine safety and vaccination intention. The analyses showed that debunking misinformation was a relevant factor, especially effective for classical vaccine types such as inactivated vaccines (see discussion of experiment 1). While some previous studies have shown that debunking health-related misinformation can also have negative effects (Nyhan et al., 2014; Nyhan & Reifler, 2015; Peter & Koch, 2015), the results of the present study strengthen the evidence for positive effects of correcting misinformation (Chan et al., 2017; Kessler & Bachmann, 2022; Paynter et al., 2019; Walter & Murphy, 2018; Yousuf et al., 2021). Although providing more detailed explanations is considered to be more effective (Chan et al., 2017; Ecker et al., 2020; Lewandowsky et al., 2020; Swire et al., 2017), the results demonstrate that short messages, which can be more easily disseminated via social media, for example, are also a promising strategy to combat misinformation and increase vaccination intentions during a pandemic.

The influence of the vaccine type on confidence and vaccination intention was more instable. However, it should be considered that the Covid-19 vaccine types were not the focus of German news coverage at the time of the experiments, and not everyone knew what type of vaccines the new Covid-19 vaccines actually are (Betsch et al., 2020a). In addition, a particular focus was on the influence of communicating a trial discontinuation because of an unexplained illness in a participant and media reports about questionable research practices of a manufacturer on confidence in vaccine safety, vaccination intention, trust in science, and willingness to participate in a vaccine trial. Information about trial discontinuation had no effects; however, the participants who were told about a classical vaccine type had higher confidence in vaccine safety when they did not receive the information, while those with a new vaccine type had similar confidence whether or not they received it. This suggests that trial discontinuations are more likely to be expected with new vaccine types and more surprising with classical vaccine types because these have already been proven in practice. However, this effect was very small and should not be overinterpreted. Information about questionable research practices had small negative effects on confidence and vaccination intention regarding the vaccine produced by that company. These effects strengthen evidence from previous research suggesting the negative effects of integrity-based scandals on trust (Bozic et al., 2019; Chen, 2008; Wang & Huff, 2007; Wingen et al., 2020) and demonstrate the importance of honest and transparent communication to prevent the emergence and spread of false and misleading information that could damage confidence and vaccination intentions. Fortunately,

information about questionable research practices did not affect other vaccines or trust in science in general. However, science is a very broad term, and it is not clear what exactly the participants understood as science. Further research should also examine trust in the pharmaceutical industry.

It should be considered that the participants may have heard about the critical events through the media or on social media before participating in the present study. In fact, the participants who knew about the vaccine trial being discontinued partially had higher confidence in the safety of the vaccine, especially when they did not know about questionable research practices, and a higher intention to get vaccinated, especially when it came to the classical vaccines. However, it should be considered that these effects were very small. Further analyses revealed that these participants were also more likely to inform themselves about Covid-19 in general and, thus, may be better informed about the vaccines and approval process. Moreover, because a trial discontinuation demonstrates that side effects are taken seriously and are reviewed, knowledge about discontinuation could increase trust in the approval system. Indeed, in the meantime, another study has examined the issue, finding that transparent communication about the negative features of Covid-19 vaccines increased trust in health authorities (Petersen et al., 2021). However, this positive, yet small, effect of trial discontinuation in the present study was shown only for real-world knowledge, not for the experimental factor information. This suggests that people who are eager to be vaccinated are also more informed, possibly more science oriented, and more likely to tolerate trial discontinuation, seeing it as a sign of trustworthiness. Also, people who heard about trial discontinuation in real life probably had more information about the event and were more likely to perceive it as being transparent information. In contrast, the information in the experiment was very brief, and the participants were not informed that the pharmaceutical company had communicated the discontinuation itself. Thus, the results of the present study only partially strengthen the evidence from previous studies suggesting the positive effects of transparent communication on trust (Auger, 2014; Jahn & Brühl, 2019) and related behaviours (Auger, 2014); further research is needed to investigate the effect of transparent communication by pharmaceutical companies.

The present study also showed that 20% and 25% of the participants, respectively, were willing to participate in a vaccine trial. This is much lower than in France (Detoc et al., 2020) or Jordan (Abu-Farha et al., 2020). In the present study, confidence in vaccine safety was most strongly associated with willingness to participate, followed by trust in science. This is consistent with previous research findings that also identified correlations between the willingness to participate in a vaccine trial and trust (Detoc et al., 2017; Jaffe et al., 2020; Pérez Guerra et al., 2012). Surprisingly, information about questionable research practices was positively related with the willingness to participate. However, this effect was very small and cannot be reasonably explained. The amount of explained variance was small, suggesting that there are other important factors related to willingness to participate in a vaccine trial.

In general, the obtained effects were rather small. One possible explanation could be that people have strong attitudes, and that providing only small pieces of information, such as explaining how a vaccine works, receiving a misinformation debunking, or reading about critical events in the vaccine trials did not shift their attitudes much. Indeed, a closer look at the distributions of the data suggested that there were partly three larger subgroups (e.g., for confidence or vaccination intention) and that there were correspondingly many people who did not want to get vaccinated at all, who are undecided or who want to get vaccinated in any case – which supports the idea of strong attitudes that are hard to change. While it may be difficult

to change strong attitudes, even small effects may make a difference in practice, e.g. when affecting societal vaccine uptake.

There are further limitations that need to be considered. First, the new Covid-19 vaccines and critical events communicated in the context of vaccine trials are real-word issues, so the participants' evaluation may have been influenced by prior knowledge. Second, the participants answered the COSMO survey questions, for example, about risk perceptions and fears related to Covid-19, directly before the experiment, which may also have biased their responses. Third, they completed the questionnaire at home, and it cannot be ruled out that they were influenced by others. Moreover, there are some limitations regarding the debunking attempt in experiment 1. As it was a one-time debunking due to the cross-sectional study design, we cannot estimate the longitudinal effects of debunking. In addition, although more detailed debunking is recommended (Lewandowsky et al., 2020), the explanations of why the presented misinformation is false and what is instead true were kept short due to space limitations in the questionnaire. Future research should thus investigate the effects of more detailed explanations and include follow-up measures at later time points to examine the duration of the debunking effects.

The results should be generalised with caution. They were drawn from a German sample and represented a snapshot of the SARS-CoV-2 pandemic when no vaccine was yet approved and available on the German market. The impact of communicating critical events in vaccine trials may not be the same in other countries because news coverage and people's perceptions are different. Moreover, vaccination intention does not necessarily reflect real-life vaccination decisions because there may be a gap between intention and actual behaviour (Sheeran, 2002). To overcome these limitations, field experiments with real-life scenarios and replications for other countries and different time points, for example, when vaccines are approved, are recommended.

Conclusion

The current study demonstrated that confidence in the safety of new vaccines is a critical factor in the Covid-19 vaccination decision which is also highly relevant for the willingness to participate in a vaccine trial. Debunking is a good response to widespread vaccination misinformation and can help with the challenge of building trust and increasing vaccination intention. Thus, actors in health communication could use this strategy to combat widespread misinformation. Furthermore, it is crucial that critical events in vaccine trials are communicated honestly and transparently to the public to prevent the occurrence of misinformation, and increase trust in science, willingness to participate in vaccine trials, and, ultimately, the intention to get vaccinated, especially when the vaccines under research are new and emerging.

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https://osf.io/hrdw8/. The third experiment's design, hypotheses, and the analysis plans were preregistered; see https://aspredicted.org/3s429.pdf

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Conflict of Interest

The authors have no conflicts of interest to disclose.

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Appendices

A. Material and Questionnaire Experiment 1

Description	**Inactivated vaccine type (classical)** (*condition vaccine type* = 0)		**Gene-based vaccine type (new)** (*condition vaccine type* = 1)	
	No debunking (*condition debunking* = 0)	**Debunking** (*condition debunking* = 1)	**No debunking** (*condition debunking* = 0)	**Debunking** (*condition debunking* = 1)
Scenario	Read everything carefully. **Now imagine the following fictitious scenario:** There is a vaccination against coronavirus on the German market. The vaccination is officially recommended for you. It is an inactivated vaccine: the vaccination contains inactive virus components that are grown in the laboratory. The inactivated vaccine effectively protects against coronavirus. Like any other medical product, inactivated vaccines can cause side effects. Side effects of inactivated corona vaccines are generally mild and disappear on their own within a few days. The most common side effects of inactivated Corona vaccines include pain, redness, and/or swelling at the injection site after vaccination, headache, fever, nausea, and muscle aches.		Read everything carefully. **Now imagine the following fictitious scenario:** There is a vaccination against coronavirus on the German market. The vaccination is officially recommended for you. It is a gene-based vaccine: the vaccination contains viral genes obtained by genetic engineering in the laboratory. The gene-based vaccine effectively protects against coronavirus. Like any other medical product, gene-based vaccines can cause side effects. Side effects of gene-based corona vaccines are generally mild and disappear on their own within a few days. The most common side effects of gene-based Corona vaccines include pain, redness, and/or swelling at the injection site after vaccination, headache, fever, nausea, and muscle aches.	
Explanation	**What is an inactivated vaccine?** According to their designation, inactivated vaccines contain only deadened pathogens. These inactivated pathogens are recognized as foreign by the body and stimulate the body's own immune system to produce antibodies without the respective disease breaking out.		**What is a gene-based vaccine?** According to their designation, gene-based vaccines contain only selected viral genes in the form of DNA or RNA, thus material that stores genetic information. With a gene-based vaccination (also: RNA vaccination), so-called messenger RNA is injected. It contains a construction plan with whose help the body's cells produce the spike protein of the virus. The cells integrate the protein into their surface, the immune system recognizes it and initiates a response.	

Debunking	Some people fear that vaccination could cause the disease. However, it is impossible for the inactivated pathogens to reproduce. Therefore, an inactivated vaccination cannot cause a disease.	Some people fear that gene-based vaccination will interfere with the human genome. However, it is impossible for the viral RNA to enter the human cell nucleus, where the human genetic material is located on the chromosomes. The material of an RNA vaccination can therefore not interfere with the human genome.
Confidence	**Please evaluate the inactivated vaccine.** I am completely confident that an inactivated vaccine against coronavirus will be safe. *(1) strongly disagree ... (7) strongly agree*	**Please evaluate the gene-based vaccine.** I am completely confident that a gene-based vaccine against coronavirus will be safe. *(1) strongly disagree ... (7) strongly agree*
Vaccination intention	How would you decide if you had the opportunity next week to get vaccinated against coronavirus with the inactivated vaccine? *(1) not at all getting vaccinated ... (7) definitely getting vaccinated*	How would you decide if you had the opportunity next week to get vaccinated against coronavirus with the gene-based vaccine? *(1) not at all getting vaccinated ... (7) definitely getting vaccinated*

B. Material and Questionnaire Experiment 2

Description	**Classical vaccine type**				**New vaccine type**			
	inactivated		**attenuated**		**vector-based**		**gene-based**	
	Information about discontinuation (condition = 1)	**No information about discontinuation** (condition = 2)	**Information about discontinuation** (condition = 3)	**No information about discontinuation** (condition = 4)	**Information about discontinuation** (condition = 5)	**No information about discontinuation** (condition = 6)	**Information about discontinuation** (condition = 7)	**No information about discontinuation** (condition = 8)
Introduction	Please read the texts on the following pages particularly carefully. Numerous clinical trials are currently underway for the development of a vaccine against COVID-19, testing many different vaccines produced using different technologies.							
Information about discontinuation	In this process, a pharmaceutical company stopped the clinical trial for its Corona vaccine in September 2020 as a precautionary measure after one of the participants developed health problems.		In this process, a pharmaceutical company stopped the clinical trial for its Corona vaccine in September 2020 as a precautionary measure after one of the participants developed health problems.		In this process, a pharmaceutical company stopped the clinical trial for its Corona vaccine in September 2020 as a precautionary measure after one of the participants developed health problems.		In this process, a pharmaceutical company stopped the clinical trial for its Corona vaccine in September 2020 as a precautionary measure after one of the participants developed health problems.	

Vaccine type	**Now please imagine the following fictitious scenario:**			
	The first vaccine is approved and available on the German market. Vaccination with this vaccine is officially recommended for you.			
	It is an **inactivated vaccine**: the vaccination contains only deadened pathogens. These inactivated pathogens are recognised as foreign by the body and stimulate the body's own immune system to produce antibodies without the respective disease breaking out. The inactivated vaccination effectively protects against coronavirus. Like any other medical product, inactivated vaccines can cause side effects. Side effects of inactivated corona vaccines are generally mild and disappear on their own within a few days. The most common side effects of inactivated Corona vaccines include pain, redness, and/or swelling at the injection site after vaccination, headache, fever, nausea, and muscle aches.	It is an **attenuated vaccine**: the vaccination contains live but highly weakened viral components. These attenuated pathogens are recognised as foreign by the body and stimulate the body's own immune system to produce antibodies without the respective disease breaking out. The attenuated vaccination effectively protects against coronavirus. Like any other medical product, attenuated vaccines can cause side effects. Side effects of attenuated corona vaccines are generally mild and disappear on their own within a few days. The most common side effects of attenuated Corona vaccines include pain, redness, and/or swelling at the injection site after vaccination, headache, fever, nausea, and muscle aches.	It is a **vector-based vaccine**: the vaccination contains a well-known harmless virus (vector) that has been adapted to serve as a transporter for components of the coronavirus. The human body recognises the components as foreign and the body's immune system is stimulated to produce antibodies without the respective disease breaking out. The vector-based vaccination effectively protects against coronavirus. Like any other medical product, vector-based vaccines can cause side effects. Side effects of vector-based corona vaccines are generally mild and disappear on their own within a few days. The most common side effects of vector-based Corona vaccines include pain, redness, and/or swelling at the injection site after vaccination, headache, fever, nausea, and muscle aches.	It is a **gene-based vaccine**: the vaccination contains selected viral genes in the form of DNA or RNA, thus material that stores genetic information. These genes are read by human cells, which then produce components of the virus themselves - e.g. the spiked proteins of the viral surface, which are recognised by the body as foreign and stimulate the body's immune system to produce antibodies without the respective disease breaking out. The gene-based vaccination effectively protects against coronavirus. Like any other medical product, gene-based vaccines can cause side effects. Side effects of gene-based corona vaccines are generally mild and disappear on their own within a few days. The most common side effects of gene-based Corona vaccines include pain, redness, and/or swelling at the injection site after vaccination, headache, fever, nausea, and muscle aches.

Confidence	Please now evaluate the **inactivated vaccine**. I am completely confident that an inactivated vaccine against COVID-19 will be safe. *(1) strongly disagree ... (7) strongly agree*	Please now evaluate the **attenuated vaccine**. I am completely confident that an attenuated vaccine against COVID-19 will be safe. *(1) strongly disagree ... (7) strongly agree*	Please now evaluate the **vector-based vaccine**. I am completely confident that a vector-based vaccine against COVID-19 will be safe. *(1) strongly disagree ... (7) strongly agree*	Please now evaluate the **gene-based vaccine**. I am completely confident that a gene-based vaccine against COVID-19 will be safe. *(1) strongly disagree ... (7) strongly agree*
Vaccination intention	How would you decide if you had the opportunity next week to get vaccinated against coronavirus with the inactivated vaccine? *(1) not at all getting vaccinated ... (7) definitely getting vaccinated*	How would you decide if you had the opportunity next week to get vaccinated against coronavirus with the attenuated vaccine? *(1) not at all getting vaccinated ... (7) definitely getting vaccinated*	How would you decide if you had the opportunity next week to get vaccinated against coronavirus with the vector-based vaccine? *(1) not at all getting vaccinated ... (7) definitely getting vaccinated*	How would you decide if you had the opportunity next week to get vaccinated against coronavirus with the gene-based vaccine? *(1) not at all getting vaccinated ... (7) definitely getting vaccinated*
Willingness to participate in a vaccine trial	Imagine that you have the opportunity to participate in a trial to test the described vaccine against COVID-19. This means that before the vaccine is approved, you will be administered the vaccine at an advanced stage of development and its tolerability and efficacy will be studied under medical supervision. Would you be willing to voluntarily participate in such a trial?			
	Imagine that it is an inactivated vaccine. *yes/no/don´t know*	Imagine that it is an attenuated vaccine. *yes/no/don´t know*	Imagine that it is a vector-based vaccine. *yes/no/don´t know*	Imagine that it is a gene-based vaccine. *yes/no/don´t know*
Knowledge about discontinua-tion	In early September 2020, a pharmaceutical company had stopped the clinical trial for its Corona vaccine as a precautionary measure after one of the participants experienced health problems. Whether the health complaints were related to the vaccine is unproven. Had you heard about it before you participated in this study? *yes/no*			

C. Material and Questionnaire Experiment 3

Description	**Information about Discontinuation**		**No Information about Discontinuation**	
	Information about questionable research practices (condition = 1)	**No Information about questionable research practices** (condition = 2)	**Information about questionable research practices** (condition = 3)	**No Information about questionable research practices** (condition = 4)
Introduction	Please read everything carefully. Numerous clinical trials are currently underway for the development of a vaccine against COVID-19, testing different vaccines for safety and efficacy.			
Information about discontinuation	In this process, the British pharmaceutical company AstraZeneca stopped the clinical trial for its Corona vaccine in September 2020 as a precautionary measure after one of the participants developed health problems.	In this process, the British pharmaceutical company AstraZeneca stopped the clinical trial for its Corona vaccine in September 2020 as a precautionary measure after one of the participants developed health problems.		
Information about questionable research practices	In November 2020, AstraZeneca announced a 70 percent efficacy rate for its vaccine. Subsequently, doubts about the results and methodology have arisen in the public domain. The reason for this was that the results of two studies were added together, although they each used different amounts of the vaccine. For example, participants in one study were given only half a dose of the vaccine instead of the full dose for		In November 2020, AstraZeneca announced a 70 percent efficacy rate for its vaccine. Subsequently, doubts about the results and methodology have arisen in the public domain. The reason for this was that the results of two studies were added together, although they each used different amounts of the vaccine. For example, participants in one study were given only half a dose of the vaccine instead of the full dose for	

	the first of two vaccinations. AstraZeneca initially stated that the differences in dose were intentional. However, in fact, the half dose was likely a manufacturing error. Instead of excluding the participants with the lower dose from the study, the design of the study was simply adjusted when the error was discovered.	the first of two vaccinations. AstraZeneca initially stated that the differences in dose were intentional. However, in fact, the half dose was likely a manufacturing error. Instead of excluding the participants with the lower dose from the study, the design of the study was simply adjusted when the error was discovered.
Scenario	**Now please imagine the following fictitious scenario:** The first vaccines are approved and available on the German market. These include the vaccine from the British pharmaceutical company AstraZeneca. The vaccines provide effective protection against the corona virus. Corona vaccination is officially recommended for you. Please evaluate the vaccines.	
Confidence (AstraZeneca vaccine)	I am completely confident that vaccination against COVID-19 with AstraZeneca's vaccine is safe. *(1) strongly disagree ... (7) strongly agree*	
Confidence (other vaccines)	I am completely confident that vaccination against COVID-19 with any of the other vaccines (except AstraZeneca's) is safe. *(1) strongly disagree ... (7) strongly agree*	
Trust in science	How much trust do you have in science to be able to deal well and properly with the novel coronavirus? *(1) very little trust ... (7) very much trust*	
Vaccination intention (AstraZeneca vaccine)	Please answer the following questions: How would you decide if you had the opportunity next week to get vaccinated against coronavirus with AstraZeneca's vaccine? *(1) not at all getting vaccinated ... (7) definitely getting vaccinated*	
Vaccination intention (other vaccines)	How would you decide if you had the opportunity next week to get vaccinated against coronavirus with one of the other vaccines (except the one from AstraZeneca)? *(1) not at all getting vaccinated ... (7) definitely getting vaccinated*	

Willingness to participate in a vaccine trial	Imagine that you have the opportunity to participate in a trial to test a vaccine against COVID-19. This means that **before the vaccine is approved**, you will be administered the vaccine at an advanced stage of development and its tolerability and efficacy will be studied under medical supervision. Would you be willing to voluntarily participate in such a trial? *(1) not at all participating... (7) definitely participating*
Knowledge about discontinuation	In early September 2020, a pharmaceutical company had stopped the clinical trial for its Corona vaccine as a precautionary measure after one of the participants experienced health problems. Whether the health complaints were related to the vaccine is unproven. Had you heard about it before you participated in this study? *yes/no*
Knowledge about questionable research practices	In November 2020, AstraZeneca announced a 70 percent efficacy rate for its vaccine. Subsequently, doubts about the results have arisen in the public due to questionable research methods. Had you heard about it before you participated in this study? *yes/no*