



Forming and updating vaccination beliefs: does the continued effect of misinformation depend on what we think we know?

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Abstract

People may cling to false facts even in the face of updated and correct information. The present study confronted misconceptions about the measles, mumps and rubella vaccine and a novel, fictitious Zika vaccine. Two experiments are reported, examining misconceptions as motivated by a poor risk understanding (Experiment 1, $N = 130$) or the exposure to conspiracy theories (Experiment 2, $N = 130$). Each experiment featured a Misinformation condition, wherein participants were presented with fictitious stories containing some misinformation (Experiment 1) and rumours focused on conspiracy theories (Experiment 2) that were later retracted by public health experts and a No misinformation condition, containing no reference to misinformation and rumours. Across experiments, participants were more hesitant towards vaccines when exposed to stories including vaccine misinformation. Notwithstanding, our results suggest a positive impact of a trusted source communicating the scientific consensus about vaccines. Zika virus represents a particular case showing how missing information can easily evolve into misinformation. Implications for effective dissemination of information are discussed.

Keywords Vaccine misinformation · Source credibility · Vaccination intent · Belief updating · Conspiracy beliefs

Introduction

The COVID-19 pandemic has blatantly revealed that misinformation about vaccines is present worldwide (Islam et al. 2021) and that people's intent to receive a vaccine against this disease decreases in the presence of misinformation, regardless of their initial intent to do so (Loomba et al.

2021). People also tend to cling to false facts even in the face of updated and correct information, a phenomenon known as the continued influence effect (Seifert 2002). There is a considerable body of evidence that individuals often cling more strongly to their initial convictions when they are exposed to new information that contradicts or disconfirms their initial beliefs (Lewandowsky et al. 2017).

Conversely, there is less evidence surrounding what takes place when people have little or no relevant knowledge about certain topics. To test whether under this condition decisions can be based on beliefs about similar issues with which people have more experience, the present study confronted misconceptions about the measles, mumps and rubella (MMR) vaccine and the Zika virus, which have captivated global attention and are surrounded by misinformation and conspiracy theories (Poland and Spier 2010; Avery 2017). Although there is great variation in vaccination confidence across countries (Larson et al. 2016), these two cases may differ in terms of their rootedness in Western European people's mind. This is so because, in these specific populations, the MMR controversy has a long tradition of ill-founded beliefs, the most enduring of which maintains that the MMR vaccine is linked to autism. In contrast, the Zika virus represents a disease about which knowledge and ill-founded

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beliefs may be relatively limited for Western Europeans. Comparing these two cases of vaccine misinformation could be of particular relevance for health communicators to prevent the spillover effect from misbeliefs about one vaccine on intention to use another. Specifically, in the absence of deeply ingrained beliefs about the Zika virus, individuals may base their intentions to vaccinate against it on beliefs about other vaccines, such as the misbelief that the MMR vaccine causes autism (Ophir and Jamieson 2018).

The experiments in this paper concern misinformation and conspiracy theories about vaccines. Conceptually, the main feature that distinguishes misinformation from conspiracy theories is that the former is relatively simple factually erroneous information whereas the latter are quite complex, elaborate narratives that typically involve secret and malevolent intent by powerful forces. Furthermore, these conspiracy narratives may align or resonate with an individual's personal, cultural or political views (Lazić and Žeželj 2021). For example, in the context of vaccination, the belief that the COVID-19 vaccine is ineffective or is dangerous to health is misinformation. In contrast, the belief that “big pharma” conspires covertly with governments to force ineffective or dangerous COVID-19 vaccines on populations in order to control them and make money is a conspiracy theory. Misinformation can spread alone. However, if it is incorporated into a conspiracy theory, the conspiracy theory is typically a more powerful and even “viral” vehicle through which items of misinformation may be spread (Lazić and Žeželj 2021).

Two experiments are reported, which examined misconceptions about the MMR vaccine and Zika virus as motivated by a poor risk understanding (Experiment 1) or the exposure to conspiracy theories (Experiment 2).

Misinformation about MMR vaccine and zika virus

Many events have the potential to erode public trust in vaccines. Sometimes, it is a new critical study that spreads misinformation about a vaccine. An example is the discredited 1988 study suggesting a causal link between the MMR vaccine and autism (Deer 2020). Over the lifetime of the MMR-autism controversy, news media, instead of emphasizing the medical consensus about vaccine safety, which is likely to be an effective pro-vaccine message (van der Linden et al. 2015), often did not include only scientific facts, but also provided opposite opinions which led to additional uncertainty (Holton et al. 2012; Dixon and Clarke 2013). Even today, despite researchers clearly rejecting the hypothesis that the MMR vaccine could trigger autism, “with the explosion of ‘contrary’ expertise online... many parents see even the most respected vaccine experts’ perspective on the issue as just one more opinion” (Gross 2009).

Another departure point for the possible emergence of misinformation are scientific uncertainties about a novel infectious disease, as in the case of Zika virus. Zika is spread by the bite of an infected mosquito, which is found throughout the tropics. The major concern is the impact that Zika can have on a pregnant woman, who can pass the virus to her foetus and cause birth defects. To date, no vaccine or treatment is available (Poland et al. 2019). Since its outbreak, Zika has been surrounded by uncertainty. Unfortunately, the lack of information about one disease could easily evolve into misinformation (Avery 2017).

Experiment 1

Risk perceptions are generally defined as people's judgments about the likelihood of negative occurrences (e.g. diseases, death) and are portrayed as having two dimensions: the cognitive dimension, which relates to how much people know and understand about risks, and the emotional dimension, pertaining to how people feel about them (Paek and Hove 2017).

Several theoretical models have been developed to explain how people perceive and process information about risks, as well as how they act on its basis (Roeser et al. 2012). A central tenet of the rational choice model of decision-making is that people evaluate the possibility of outcomes after they calculate potential costs and benefits (Simon 1955). However, the weight of scientific information is higher among experts, who tend to engage in such analytic and effortful behaviour, relying on scientific information and objective assessment. By contrast, laypeople evaluate risks mostly according to their subjective experiences or emotions and rely on all sorts of biases and heuristics (Kahneman 2011).

Risk perceptions are important precursors of future actions; thus, interventions that change risk perceptions may subsequently change health behaviours (Sheeran et al. 2014). For instance, Horne et al. (2015) succeeded in altering people's anti-vaccination attitudes by making them appreciate the consequences of failing to vaccinate their children, but this can also lead to distrust in vaccination (Attwell 2019). The present experiment examined whether misconceptions about MMR and Zika vaccines are altered in the presence or absence of common misinformation about vaccination. We also investigated the influence of credibility of expert opinion on debunking misinformation and how all these factors impact people's vaccine attitudes and willingness to vaccinate their children.

In particular, we made a series of predictions. First, as misinformation has proved to negatively impact on beliefs and attitudes towards vaccination (Nyhan et al. 2014; Pluviano et al. 2017, 2019), we anticipated that:

Hypothesis 1 Misconceptions about the risks of the MMR vaccine and Zika virus would be higher when misinformation was presented than when no misinformation was presented.

Then, we supposed that the cases of the MMR vaccine and Zika virus might differ in terms of the cognitive processing underlying people's beliefs, in that convictions in unproven MMR vaccine–autism theories, because of their rootedness in people's minds, might be more resistant to correction attempts than false beliefs about Zika virus, a relatively novel disease with limited scientific evidence from which to draw conclusions. Therefore, we expected that participants would be relatively familiar with the MMR vaccine misconceptions, whereas the Zika virus vaccine misconceptions would be unfamiliar. Accordingly, we proposed that:

Hypothesis 2 Misconceptions would be higher in the case of the MMR than in the case of Zika virus vaccine.

Moreover, as previous research has shown that misinformation may negatively impact on parents' stated intention to vaccinate their children (Nyhan et al. 2014; Pluviano et al. 2017, 2019), we also proposed that:

Hypothesis 3 Misconceptions about the MMR and Zika virus vaccine would be negatively associated with the stated intention to vaccinate, so that participants who had more misconceptions would report a lower intention to vaccinate their child.

Finally, given the lack of confidence in science and in expert opinion, which can influence the effectiveness of the messages aimed at correcting vaccine misconceptions (Hovland et al. 1953; Pluviano et al. 2020) that abounds not only in the media, but also in laypeople conversation and social networks exchanges, we also proposed that:

Hypothesis 4 Credibility evaluations of public health experts who retracted the misconception would be negatively associated with vaccine misconceptions and hesitancy, so that participants who put less trust in the source providing the correction would have more misconceptions, report a lower intention to vaccinate their child (vaccine hesitancy) and more negative attitudes towards vaccines.

Method

Participants A priori power analysis (G*Power 3; Faul et al. 2007) for a one-way ANOVA with 2 groups suggested a minimum sample size of 128 participants to detect a medium size effect of $f=0.25$, with $\alpha=0.05$ and $1-\beta=0.80$. We decided to test 130 students from the University of

Florence, Italy, half randomly assigned to the *No misinformation* condition (20 males and 45 females, average age $M=24.81$, $SD=2.95$) and half to the *Misinformation* condition (32 males and 33 females, average age $M=25.15$, $SD=3.1$). Participants were informed that the experiment involved answering questions about texts that would be read and about health issues. They were not told that the texts were hypothetical. They all participated on a voluntary basis and were tested in groups immediately before or after their classes. Groups were equivalent in terms of age and type of subject they were studying. To protect the independence and privacy of their responses, participants were requested not to talk to each other while reading the stories and filling out the questionnaires and a proper seating distance was maintained between them. Participants were unaware of the other experimental condition and also researchers were blind to assignment. All participants gave their verbal informed consent to take part in the study, which took place before the COVID-19 pandemic. The study received ethical approval from the University of Edinburgh's Ethics Committee, according to the main affiliation of the first author.

Procedure All participants were presented with two fictitious stories, presented in a fixed order (see Online Appendix 1). The first story was about a baby developing autism after receiving the MMR vaccine. The second story was about a baby developing epilepsy after receiving a fictitious vaccine against Zika virus. Participants were assigned to one of two conditions. In the *Misinformation* condition, both stories contained a critical piece of misinformation linking autism to MMR and epilepsy to Zika vaccines, which was later retracted by public health experts. In the first story about the MMR vaccine, there was a rumour about the alleged link between the MMR vaccine and autism, while in the second story about Zika virus there was a rumour about the alleged link between Zika virus and epilepsy. In the *No misinformation* condition, both autism and epilepsy are presented as having occurred after vaccination but there was no reference in either story to rumours about the correlation of vaccination with these clinical conditions. After reading the stories, all participants were asked to complete a short distraction task to prevent rehearsal of the stories. Then, they were given an unannounced free-recall test, in which they were asked to write everything they remembered reading in the stories as accurately as possible. After the free-recall test, participants completed a questionnaire (see Online Appendix 2) assessing misconceptions about the MMR and Zika virus vaccine, the intention to vaccinate one's child, negative attitudes towards vaccination and, in the Misinformation conditions only, the perceived credibility of the correction received from public health experts. Additionally, in the questionnaire, after providing some demographic details (sex, age, education level),

participants were asked whether they had any children and had ever delayed or refused a recommended vaccine for their child(ren). Various scales were included in the questionnaire, as detailed below:

Misconceptions about the risks associated with the MMR and Zika virus vaccine Misconceptions about the MMR vaccine were evaluated by two questions used in previous studies (Freed et al. 2010; Nyhan et al. 2014; Pluviano et al. 2017, 2019). First, participants were asked to indicate whether they agree or disagree that “MMR vaccine causes autism in healthy children” on a 5-point scale from “strongly disagree” (1) to “strongly agree” (5). Then, they were asked to indicate the perceived likelihood that “children will suffer serious side effects from MMR vaccine” on a 6-point scale from “very unlikely” (1) to “very likely” (6). These two items were averaged, with a higher score indicating greater misconceptions about MMR vaccine. (Values were transformed to yield equivalent proportions, with values ranging from 1 to 6).

Misconceptions about Zika virus vaccine were also evaluated by two questions. First, participants were asked to indicate whether they agree or disagree that “Zika virus vaccine causes epilepsy in healthy children” on a 5-point scale from “strongly disagree” (1) to “strongly agree” (5). Then, they were asked to indicate the perceived likelihood that “children will suffer serious side effects from Zika virus vaccine” on a 6-point scale from “very unlikely” (1) to “very likely” (6). Scores were equivalent to those for misconceptions about MMR vaccine risks, with a higher score indicating greater misconceptions about the fictitious Zika virus vaccine.

Vaccines hesitancy Vaccination intent was evaluated by asking participants how likely they would be to give the MMR vaccine to their child(ren) on a 6-point scale from “very likely” (1) to “very unlikely” (6), a question which has been used in previous studies (Freed et al. 2010; Nyhan et al. 2014; Pluviano et al. 2017, 2019). Then, participants were asked to evaluate how likely they would be to give a possible vaccine against Zika virus to their child (ren) on the same 6-point scale from “very likely” (1) to “very unlikely” (6). Therefore, higher scores indicate greater vaccine hesitancy.

Negative attitudes towards vaccination Attitudes towards vaccination were evaluated by 8 questions, which have been used in previous studies (Freed et al. 2010; Nyhan et al. 2014; Pluviano et al. 2017, 2019). These questions covered common attitudes from both the pro- (e.g. “Getting vaccines is a good way to protect my future child (ren) from disease”) and the anti-vaccination side (e.g. “Some vaccines cause autism in healthy children”). Participants were asked to indicate their degree of agreement with each statement on a 5-point Likert scale, ranging from “strongly disagree” (1) to “strongly agree” (5). After reverse coding, average

scores were computed, so that higher means indicated more negative attitudes towards vaccination.

Credibility evaluations of public health experts Participants in the *Misinformation* condition were also asked to evaluate the credibility of the correction received from public health experts. Two out of the three subdimensions composing Ohanian’s (1990) scale were used, namely the *expertise* and *trustworthiness* subscales. We chose these two subscales because extant literature indicates that the notion of credibility encompasses two core dimensions: *expertise*, namely the extent to which the communicator is perceived to be capable of making correct assertions and *trustworthiness*, which is the willingness of the communicator to provide the assertions he or she considers most valid (Hovland et al. 1953). Both Ohanian’s (1990) subscales consisted of five pairs of oppositional adjectives (antonyms) rated on a 7-point scale like a semantic differential. The descriptive pairs for measuring expertise included: an expert–not an expert; inexperienced–experienced; unknowledgeable–knowledgeable; qualified–unqualified; and unskilled–skilled. The descriptive pairs that measure trustworthiness were: dependable–undependable; dishonest–honest; unreliable–reliable; insincere–sincere; and trustworthy–untrustworthy. After reverse coding, average scores were computed for both subscales, with scores ranging from 1 to 7, so that higher means indicated a higher credibility rating.

Results

The free-recall test was scored using “idea units” (see Wilkes and Leatherbarrow 1988). Each idea unit corresponded to one of the 14 messages in which each story was organized. An idea unit was recorded as being recalled and received a score of 1 if the participant reproduced all or a substantial part of its content; otherwise it was scored as absent and received a score of 0. Since all participants read two stories, the highest possible individual score on the free-recall test was 28. Results revealed that participants’ overall recall performance did not differ across conditions [No misinformation condition = 22.03 ± 2.07 (mean \pm SD); Misinformation condition = 21.10 ± 2.07 ; $F(1, 129) = 0.352$, $p = 0.554$]. Therefore, any differences between conditions were not attributable to one condition being more memorable than the other.

Descriptive statistics regarding the scores in the questionnaires for Experiment 1 are reported in Table 1.

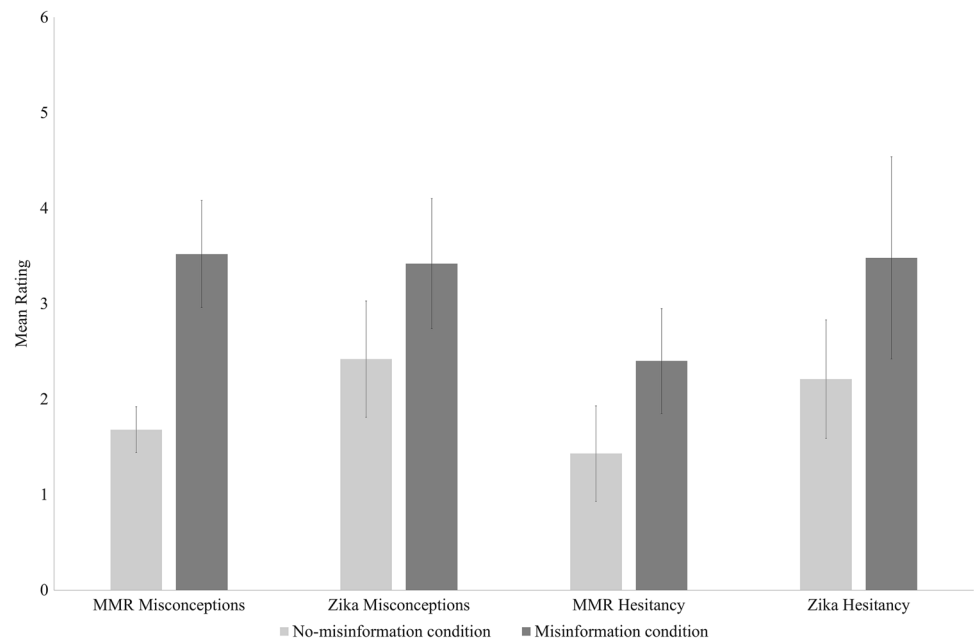
A series of ANOVAs was performed to test our hypotheses. Figure 1 displays the results relevant to Hypotheses 1, 2 and 3. First, we tested Hypothesis 1, which posited that misconceptions about the risks of the MMR vaccine and Zika virus would be higher in the *Misinformation* than in the *No misinformation* condition. As expected, significant differences in misconceptions about the MMR vaccine [$F(1,$

Table 1 Descriptive statistics (mean \pm SD scores) for the questionnaire rating outcomes of Experiment 1 (No Misinformation and Misinformation conditions) and Experiment 2 (No Conspiracy and Conspiracy conditions)

Condition	Outcome							
	Experiment 1				Experiment 2			
	No misinformation		Misinformation		No conspiracy		Conspiracy	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Conspiracy misconceptions about the MMR vaccine	1.68	0.24	3.52	0.56	1.77	0.47	3.30	1.01
Conspiracy misconceptions about the zika virus vaccine	2.42	0.61	3.42	0.68	2.23	0.55	3.46	0.96
MMR hesitancy (unwillingness to vaccinate offspring)	1.43	0.50	2.40	0.55	2.51	0.64	4.72	0.89
Zika hesitancy (unwillingness to vaccinate offspring)	2.21	0.62	3.58	1.06	2.94	0.58	4.26	1.21
Negative attitudes towards vaccination	2.82	0.18	3.21	0.23	2.17	0.20	2.51	0.28
Perceived expertise of public health experts	–	–	3.94	0.29	–	–	2.84	0.39
Perceived trustworthiness of public health experts	–	–	3.38	0.25	–	–	1.61	0.45

Ratings ranged from 1 to 6; *MMR* Measles, mumps and rubella

Fig. 1 Mean (\pm SD) ratings of misconceptions about MMR and Zika vaccine and hesitancy to vaccinate offspring against both diseases in the No. Misinformation condition and misinformation conditions in Experiment 1 *MMR* Measles, mumps and rubella; For statistical effects, see text



128) = 599.90, $p < 0.001$, $\eta^2 = 0.82$] and Zika virus vaccine [$F(1, 128) = 77.66$, $p < 0.001$, $\eta^2 = 0.38$] were found, with participants in the *Misinformation* condition having higher misconceptions ($M = 3.52$, $SD = 0.56$ for the MMR vaccine; $M = 3.42$, $SD = 0.68$ for Zika virus vaccine) than those in the *No misinformation* condition ($M = 1.68$, $SD = 0.24$ for the MMR vaccine; $M = 2.42$, $SD = 0.61$ for Zika virus) (effect size for MMR, $d = 3.52$; for Zika, $d = 1.55$).

Next, we tested Hypothesis 2, which predicted that misconceptions would be higher in the case of the MMR vaccine than in the case of Zika virus, irrespective of the misinformation manipulation. The analyses did not support Hypothesis 2. In fact, a within-subjects ANOVA conducted to determine whether there was a statistically significant

difference between MMR and Zika vaccine misconceptions was significant [$F(1, 129) = 15.53$, $p < 0.001$, $\eta^2 = 0.11$], with participants having lower and not higher misconceptions when questioned about their beliefs about the MMR vaccine ($M = 2.60$, $SD = 1.02$) as opposed to their beliefs about Zika virus vaccine ($M = 2.92$, $SD = 0.82$) ($d = 0.35$).

We then tested Hypothesis 3, which posited that vaccine hesitancy would be higher in the *Misinformation* than in the *No misinformation* condition. Significant differences in MMR [$F(1, 129) = 109.964$, $p < 0.001$, $\eta^2 = 0.462$] and Zika [$F(1, 129) = 80.595$, $p < 0.001$, $\eta^2 = 0.386$] vaccine hesitancy were found, with participants in the *Misinformation* condition being more hesitant towards the MMR vaccine and a possible shot against Zika virus ($M = 2.4$, $SD = 0.55$ for

the MMR vaccine; $M=3.58$, $SD=1.05$ for Zika virus) than participants in the *No misinformation* condition ($M=1.43$, $SD=0.5$ for the MMR vaccine; $M=2.21$, $SD=0.62$ for Zika virus). The results also indicated that there was a significant between-participant difference in negative attitudes towards vaccination [$F(1, 129)=118.123$, $p<0.001$, $\eta^2=0.48$], with participants in the *Misinformation* condition having more negative attitudes ($M=3.21$, $SD=0.23$) than those in the *No misinformation* condition ($M=2.82$, $SD=0.18$) ($d=1.89$). As further confirmation of the expected misinformation effect, MMR misconceptions linearly and positively correlated (Pearson correlations) with MMR hesitancy ($r=0.67$, $p<0.01$) and negative attitudes towards vaccination ($r=0.65$, $p<0.01$); similarly, Zika vaccine misconceptions positively correlated with Zika hesitancy (small effect: $r=0.20$, $p<0.05$) and negative attitudes towards vaccination ($r=0.36$, $p<0.01$). Therefore, participants having higher misconceptions about the MMR and Zika virus vaccine reported a lower intention to vaccinate their child and more negative attitudes towards vaccination in general.

Finally, we tested Hypothesis 4, which predicted that lower credibility evaluations of public health experts (expertise and trustworthiness) would be associated with stronger vaccine misconceptions and hesitancy and higher negative attitudes. The analyses only partially supported Hypothesis 4 (see Table 2). The perceived expertise of the source providing the correction negatively correlated with MMR vaccine hesitancy ($r=-0.29$, $p<0.05$), so that the more the perceived expertise of the source, the higher the vaccination intent. In a similar vein, the perceived trustworthiness of the source providing the correction negatively correlated with

Zika misconceptions ($r=-0.35$, $p<0.01$), so that the more the perceived trustworthiness of the source, the fewer misconceptions were held about Zika virus vaccine.

Discussion

Results from Experiment 1 demonstrated the lingering effect of misinformation, as individuals presented with misinformation that was later corrected showed more vaccine risk misconceptions (Hypothesis 1) and were more hesitant towards vaccines (Hypothesis 3) than those exposed to a *No misinformation* condition with no misinformation presented. Contrary to expectation, misconceptions regarding a novel vaccine (Zika) vaccine were higher than misconceptions about a familiar vaccine (MMR) (contrary to Hypothesis 2). Hypothesis 4 was partially supported: the higher the perceived expertise of the source, the higher the vaccination intent for MMR vaccine and the higher the perceived trustworthiness of the source, the fewer misconceptions were held about Zika virus vaccine.

Experiment 2

Besides biased risk appraisal, a key psychological factor that may motivate people to reject scientific consensus around vaccination is conspiratorial thinking, namely the tendency to explain events as the secret acts of malevolent forces (Grimes 2016). Parents who believe in anti-vaccine conspiracy theories are less likely to vaccinate their child (Jolley and Douglas 2014). Understanding how conspiracy theories may impact on vaccine beliefs therefore becomes crucial for health communicators. For this reason, Experiment 2 examined the persistence of misconceptions about the MMR and Zika virus vaccine as motivated by the exposure to conspiracy theories. This experiment tested most of the hypotheses of Experiment 1: Would misconceptions about risk of vaccines be higher when conspiracy theory was present? (Hypothesis 1); Would exposure to conspiracy theories lead to less intent to vaccinate offspring? (Hypothesis 3); and finally, would less trust in the source (experts who debunked misconceptions) be associated with higher misconceptions and lower intention to vaccinate offspring? (Hypothesis 4). However, we could not rule out the possibility that misconceptions about the MMR and Zika virus vaccine as motivated by conspiracy theories would be equivalent, because the idea that vaccines are part of a conspiracy may be widespread both in the case of “already known” vaccines as the MMR vaccine and in the case of “new” vaccines such as a possible vaccine against Zika virus. Therefore, these possible differences were also been considered (Hypothesis 2).

Table 2 Linear Pearson intercorrelation (r) of ratings regarding expert credibility (expertise and trustworthiness) versus negative attitudes towards vaccines, vaccine misconceptions and hesitancy (unwillingness to vaccinate offspring) in both experiments

Variables	Expertise	Trustworthiness
<i>Experiment 1</i>		
Negative attitudes	-0.13	0.17
Misconceptions (MMR)	-0.18	-0.12
Misconceptions (Zika)	-0.11	-0.35*
Hesitancy (MMR)	-0.29*	-0.07
Hesitancy (Zika)	0.06	0.21
<i>Experiment 2</i>		
Negative attitudes	-0.03	0.06
Misconceptions (MMR)	0.23	0.08
Misconceptions (Zika)	0.02	-0.11
Hesitancy (MMR)	-0.14	-0.13
Hesitancy (Zika)	-0.26*	-0.36*

* $p<0.05$; MMR Measles, mumps and rubella; ratings of attitudes, expertise and trustworthiness were common to stories about MMR (measles, mumps and rubella) and Zika virus vaccine

Method

Participants As in Experiment 1, we tested 130 students from the University of Florence, half randomly assigned to the *No conspiracy* condition (27 males and 38 females, average age $M=23.06$, $SD=2.77$) and half to the *Conspiracy* condition (21 males and 44 females, average age $M=24.6$, $SD=3.15$). Participants were informed of the purpose and procedure of the study in the same way as in Experiment 1. None of the participants in this experiment had taken part in Experiment 1. All participants gave their verbal informed consent to take part in the study. The study received ethical approval from the University of Edinburgh’s Ethics Committee.

Procedure All participants were presented with two fictitious stories (see Online Appendix 1), both in either one of two conditions (*Conspiracy* or *No conspiracy*). The first story was about a baby developing measles because he was not immunized with the MMR vaccine. The second story was about a baby being diagnosed with Guillain-Barré syndrome (GBS) after a mosquito bite. Both stories then mention that there are vaccines that protect against these disorders. In the *Conspiracy* condition, both stories contained an added critical piece of misinformation, which is later retracted by public health experts. In particular, in both stories the misinformation consisted of mentioning rumours claiming the MMR and Zika virus vaccines were just part of a conspiracy to make money for pharmaceutical companies. In the *No conspiracy* condition, there was no reference to these rumours or to their correction. As in Experiment 1, after reading the stories, all participants were asked to complete a short distraction task to prevent rehearsal of the stories. Then, without prior notice, participants were asked to write everything they remembered reading in the stories as accurately as possible. After this free-recall test, participants completed a questionnaire (see Online Appendix 2) as in Experiment 1. Scales assessing the intention to vaccinate one’s child, negative attitudes towards vaccination and the perceived credibility of the correction received from public health experts (this latter just in the *Conspiracy* condition) were the same as those administered in Experiment 1. However, misconceptions about the MMR and Zika virus vaccine were assessed by means of different questions. In particular, conspiracy misconceptions about the MMR and Zika virus vaccine were evaluated by means of two questions. Participants were asked to indicate whether they agree or disagree, both in the case of MMR and in the case of Zika, that “viral experts are in the pocket of pharmaceutical companies” and “vaccines are nothing more than a pharmaceutical company conspiracy to make money” on a 5-point scale from “strongly disagree” (1) to “strongly agree” (5). These two questions were asked twice, one time referring to the MMR vaccine and a second time to the fictional vaccine against

Zika virus. These two items were averaged, with a higher score indicating greater conspiracy misconceptions about the MMR and Zika virus vaccine, respectively.

Results

Similarly to Experiment 1, the free-recall test was scored using “idea units”. Results revealed that participants’ overall recall performance did not differ across conditions [No conspiracy condition = 22.91 ± 1.88 (mean \pm SD); Conspiracy condition = 22.98 ± 1.96 ; $F(1, 129)=0.052$, $p=0.82$]. Therefore any differences between conditions were not attributable to one condition being more memorable than the other.

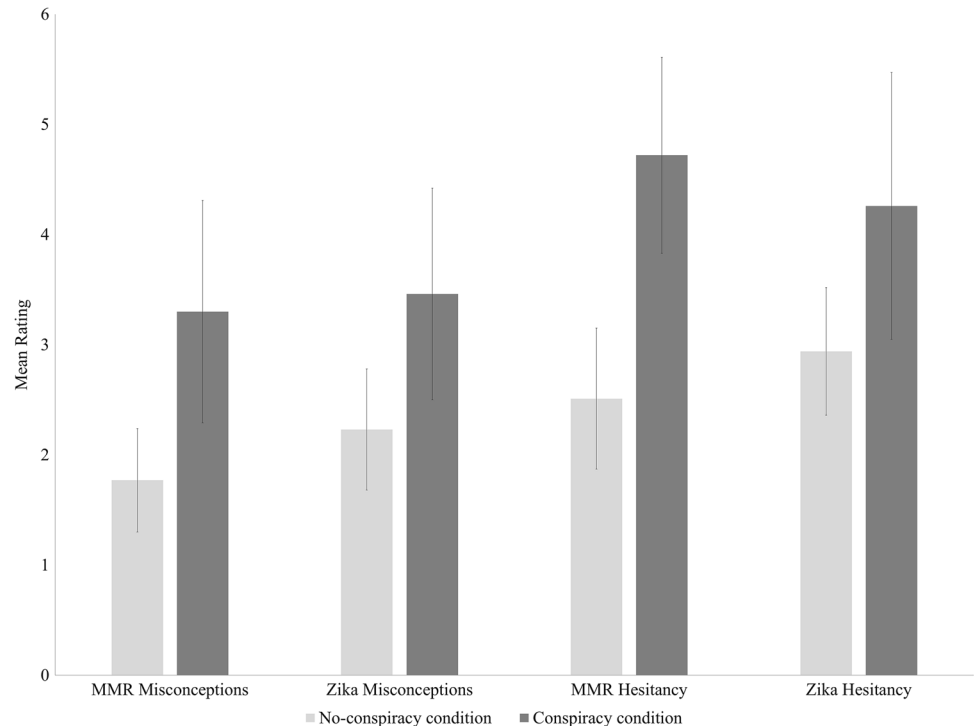
Descriptive statistics regarding scores in the questionnaires for Experiment 2 are reported in Table 1.

A series of ANOVAs was performed to test our hypotheses. Figure 2 displays results relevant to Hypothesis 1 and 3 and to the novel research question. First, we tested Hypothesis 1, which posited that misconceptions about the MMR and Zika virus vaccine would be higher in the *Conspiracy* than in the *No conspiracy* condition. As expected, significant differences in misconceptions about the MMR vaccine [$F(1, 128)=122.05$, $p<0.001$, $\eta^2=0.49$] and Zika virus [$F(1, 128)=80.16$, $p<0.001$, $\eta^2=0.39$] were found, with participants in the *Conspiracy* condition having higher misconceptions ($M=3.30$, $SD=1.01$ for the MMR vaccine; $M=3.46$, $SD=0.96$ for Zika virus) than those in the *No conspiracy* condition ($M=1.77$, $SD=0.47$ for the MMR vaccine; $M=2.23$, $SD=0.55$ for Zika virus (effect sizes MMR, $d=4.50$; for Zika, $d=1.57$)).

Next, to address the novel research question (Hypothesis 2), which asked whether conspiracy misconceptions about the MMR and Zika virus vaccine would differ, a within-subjects ANOVA was conducted, irrespective of the misinformation manipulation. The results were significant [$F(1, 129)=10.00$, $p=0.002$, $\eta^2=0.07$], with participants having lower misconceptions when questioned about their beliefs about the MMR vaccine ($M=2.53$, $SD=1.10$) as opposed to their beliefs about Zika virus vaccine ($M=2.85$, $SD=1.00$) ($d=0.30$).

We then tested Hypothesis 3, which posited that vaccines hesitancy would be higher in the *Conspiracy* than in the *No conspiracy* condition. Significant differences in the MMR [$F(1, 129)=264.258$, $p<0.001$, $\eta^2=0.674$, $d=2.85$] and Zika [$F(1, 129)=62.612$, $p<0.001$, $\eta^2=0.328$, $d=1.36$] vaccine hesitancy were found, with participants in the *Conspiracy* condition being more hesitant towards the MMR vaccine and a possible shot against Zika virus ($M=4.72$, $SD=0.89$ for the MMR vaccine; $M=4.23$, $SD=1.21$ for Zika virus) than participants in the *No conspiracy* condition ($M=2.51$, $SD=0.64$ for the MMR vaccine; $M=2.94$, $SD=0.58$ for Zika virus). The results also indicated that there was a significant difference in negative

Fig. 2 Mean (\pm SD) ratings of misconceptions about MMR and Zika vaccine and hesitancy to vaccinate offspring in the No conspiracy and conspiracy conditions in Experiment 2. *MMR* Measles, mumps and rubella; For statistical effects, see text



attitudes towards vaccination [$F(1, 129) = 63.802, p < 0.001, \eta^2 = 0.333$], with participants in the *Conspiracy* condition having more negative attitudes ($M = 2.17, SD = 0.20$) than those in the *No conspiracy* condition ($M = 2.82, SD = 0.18$) ($d = 3.42$). As further confirmation of the expected misinformation effect, MMR misconceptions positively correlated with MMR hesitancy ($r = 0.670, p < 0.01$) and negative attitudes towards vaccination ($r = 0.355, p < 0.01$); similarly, Zika vaccine misconceptions positively correlated with Zika hesitancy ($r = 0.335, p < 0.01$) and negative attitudes towards vaccination ($r = 0.355, p < 0.01$), so that participants having higher misconceptions about the MMR and Zika virus vaccine reported a lower intention to vaccinate their child and more negative attitudes towards vaccination in general.

Finally, we tested Hypothesis 4, which predicted that lower credibility evaluations of public health experts (their expertise and trustworthiness) would be associated with stronger misconceptions and stronger vaccines hesitancy (unwillingness to vaccinate offspring) and also higher negative attitudes towards vaccines. The analyses only partially supported Hypothesis 4 (see Table 2). The perceived expertise of the source providing the correction negatively correlated with negative attitudes towards vaccination ($r = -0.246, p < 0.05$), so that the greater the perceived expertise of the source, the higher the disposition towards vaccination. Similarly, the perceived trustworthiness ($r = -0.36, p = 0.003$) and expertise ($r = -0.26, p = 0.04$) of the source providing the correction negatively correlated with Zika vaccine hesitancy, so that the more the perceived

trustworthiness/expertise of the source, the less Zika vaccine hesitancy. These effects were not significant in the manipulations regarding the MMR vaccine.

Discussion

The findings from Experiment 2 replicated those from Experiment 1, as individuals presented with misinformation (conspiracy theories) that was later corrected showed more vaccine misconceptions (Hypothesis 1) and were more hesitant towards vaccines than those exposed to the *No conspiracy* condition (Hypothesis 3). Once again, Zika misconceptions were higher than MMR misconceptions (contrary to Hypothesis 2), although hesitancy to vaccinate against Zika decreased when credible sources provided corrections of misconceptions, which did not occur in the case of MMR (partially supporting Hypothesis 4).

General discussion

Recent accounts warn about spillover effects from misbeliefs about one vaccine on intention to use another (Ophir and Jamieson 2018). In two experiments, we confronted the persistence of misconceptions about the MMR vaccine and Zika virus as motivated by a poor risk understanding (Experiment 1) and exposure to conspiracy theories (Experiment 2).

The findings confirmed the hypothesis about the continued influence effect of misinformation. In both Experiments

1 and 2, misconceptions about the risks of MMR vaccine and Zika virus were higher (large effect sizes) in the *Misinformation/Conspiracy* condition as compared to the *No misinformation/No conspiracy* condition. Moreover, in both Experiments 1 and 2 vaccine hesitancy was higher in the *Misinformation/Conspiracy* than in the *No misinformation/No conspiracy* condition. These data are in line with those reported by Loomba et al. (2021), who found that presenting misinformation about COVID-19 vaccination decreased intent to vaccinate by up to around 6%. Importantly, misconceptions were lower in the case of the MMR vaccine than in the case of Zika virus, although effect sizes were small. This finding was replicated in Experiment 2, with a similar magnitude. One plausible explanation is that Zika virus represents a peculiar case showing how missing information can easily evolve into misconceptions. As anticipated in Introduction, Zika is a relatively novel disease that is not present in the participants' country of origin. Hence, they received less coverage in European traditional media outlets than the MMR vaccine. While the evidence about the safety of the MMR vaccine is solid, scientists are still learning about Zika, with the public and the media struggling to keep up (Bode and Vraga 2018). This uncertainty may have intensified the negative impact of misinformation about Zika. Some evidence seems to corroborate this reasoning. For example, a meta-analysis of the efficacy of messages countering misinformation pointed out that, when trying to set the record straight, simply labelling the misinformation as wrong is less effective than debunking it with new details (Chan et al. 2017). In fact, a key element for an effective rebuttal is replacing misinformation with an alternative causal account covering the "gap" created in people's understanding or mental model of the events. In Experiment 1, although the correction we provided did not feature a detailed explanation of the reasons why the link between MMR and autism was false, at least participants were informed that "signs of autism typically appear around the same time that children are recommended to receive the MMR vaccine". Instead, no explanation of the alleged link between the hypothetical Zika vaccine and epilepsy was provided; participants were just advised that there was no connection between the two. Additionally, as this link was proposed only in this experiment, participants would not have had a chance of having heard about alternative explanations as they may have done in the case of the MMR vaccine. Therefore, in Experiment 1 people might have been more resistant to the misinformation related to the MMR vaccine because they might have been already exposed (both inside and outside the laboratory) to corrections detailing why the link between the MMR vaccine and autism was false. Conversely, in the case of Zika, they could have continued to rely on misinformation in order to account for otherwise unexplained events (if Zika does not explain epilepsy, what does?).

Similarly, reference (or absence of reference) to causal accounts could explain the results of Experiment 2, showing that conspiracy theory endorsement was higher for Zika than MMR. Indeed, misinformation flourishes when there is missing information as in the case of Zika, because people tend to think that there are "cover-ups" (Nyhan et al. 2016). As to why people might be motivated to accept conspiracy theories, taking a psychodynamic perspective conspiracy beliefs may be described as giving "causes and motives to events that are more rationally seen as accidents...[in order to] bring the disturbing vagaries of reality under...control" (Pipes 1997, p. 181). Furthermore, one point that deserves attention is that while in Experiment 1 the hypothetical Zika vaccine is linked to epilepsy, in Experiment 2 it is associated with GBS, which may have an impact in vaccine misconceptions, as GBS is less familiar than epilepsy.

Finally, our results stress the importance of a trusted source (Guillory and Geraci 2013; Pluviano et al. 2020), who may diminish vaccine misconceptions (Experiment 1), and increase the stated intention to vaccinate one's child (Experiment 2). This applied most to results in respect to Zika, which may represent new/unknown diseases, for which there may be more room for persuasion about scientific facts than in cases in which there are consolidated misbeliefs, as occurred for the MMR vaccine (Seifert 2002). This calls for quick action from healthcare policy makers in promoting science dissemination when new vaccines become available, such as is the case of COVID-19, although source credibility alone does not guarantee reduction of misinformation (Guillory and Geraci 2013). Combating false facts is no easy feat, but various strategies have been proposed to enhance the effectiveness of science communication (Lewandowsky et al. 2017; Cook et al. 2018), including approaches that specifically target vaccine hesitancy (Vanderpool et al. 2020; Islam et al. 2021).

This study was not designed to allow direct cross-experiment comparisons. Nonetheless, it is noteworthy that visual inspection of the data suggests a different pattern of results regarding vaccine hesitancy, which was substantially higher in Experiment 2. One might expect that, because the stories in Experiment 1, unlike Experiment 2, make implicit temporal (causal) associations between vaccines and diseases, vaccine hesitancy would be higher in Experiment 1. While we cannot provide a substantiated explanation for this difference because the stories were not formulated to be directly comparable, we have some conjectural explanations: (1) Although the samples used in both experiments were similar in terms of demographics, it cannot be excluded that the sample of Experiment 2 was less trusting of vaccines before taking part in the study; (2) There is some evidence that people who distrust vaccines feel more hesitant when pro-vaccine campaigners present the pros of preventing diseases and avoid discussing vaccine-induced negative effects

(see Attwell 2019). This could explain higher hesitancy in Experiment 2 in which the stories in the *No Conspiracy* conditions do exactly this. This is taken to extremes in the Conspiracy conditions, in which it is mentioned that “some people are convinced” that the mentioned diseases are not serious, which is clearly not the case if the gravity of the symptoms described in the stories is to be believed.

Some limitations of the present study should be mentioned. One concerns the use of similar questions for different texts and the risk of prior questions affecting participants’ responses to later questions in the questionnaires administered. Secondly, our study design had only two conditions—misinformation/conspiracy with retraction and no misinformation/conspiracy. It is not known how participants would have responded to misinformation/conspiracy *without* retraction, and a future study including this condition may clarify this question. Another issue concerns the unlikely presence of mosquitos carrying Zika in Italy, which might have influenced individuals’ responses. Therefore, in our sample participants might have perceived Zika virus as less of a threat than measles, mumps or rubella and, purely for pragmatic reasons, would be more hesitant towards Zika than MMR vaccination. Furthermore, autism could also have been regarded as a more severe outcome than epilepsy, which is treatable. Further studies should also include two different “*No misinformation* conditions”, one “true” *No misinformation* condition where the story of the vaccinated child diagnosed with autism is not mentioned at all, along with another condition where the story is presented without correction. Furthermore, it cannot be excluded that the differences in prior knowledge about and/or perception of the severity of vaccine preventable diseases mentioned in Experiment 1 (autism and epilepsy) and Experiment 2 (measles and GBS) could have differently influenced participants’ answers because these factors can be promoters or barriers to vaccination (see Larson et al. 2014). As severity of distinct illnesses is unlikely to be similar, future studies that compare vaccines must control for possible asymmetric effects by requiring participants to rate how severe they believe these illnesses are. We also only tested young and highly schooled Italian graduate students, so results may not generalize to other populations, especially as various demographic variables have been found to influence vaccine hesitancy and the impact of misconceptions about vaccines in developing and developed nations (see Abedin et al. 2021; Loomba et al. 2021). Nonetheless, we presented evidence of spillover effects of misconceptions about the MMR vaccine to Zika virus vaccine that little knowledge about a disease can increase beliefs in conspiracy theories and that these effects can be reduced by presenting corrective information from credible sources, pending confirmation in samples with different demographic characteristics since vaccine hesitancy is a multifactorial issue that varies across cultures, time and

type of vaccine (Larson et al. 2014, 2016). Future studies must strive to build psychometrically validated questionnaires about the possible reasons for subjective feelings about each type of vaccine, their hesitancy towards them and what aspects of vaccine experts lead people to mistrust their opinions. Here, we used questions about these issues that have been shown in other studies to capture some aspects of people’s negative feelings towards vaccines/experts. We did not analyse them individually to avoid inflating type I errors but, rather, averaged scores across them in order to maximize our chances of detecting these impressions that could change according to the type of information presented in the tested texts. We did not, however, assume that these questions would contribute equally to the averaged scores (have similar weights), which likely depends on the types of vaccine.

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Data availability The data that support the findings of this study are openly available on Open Science Framework at <https://osf.io/g79rk/>

Declarations

Conflicts of interest All authors declare that they have no conflict of interest.

Ethics approval Ethical approval for this study was obtained from the University of Edinburgh’s Ethics Committee.

Consent to participate All participants gave their verbal informed consent to take part in the study.

Consent for publication All authors consented to publication of the study.

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