SOCIAL SCIENCES

The effects of corrective information about disease epidemics and outbreaks: Evidence from Zika and yellow fever in Brazil

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Disease epidemics and outbreaks often generate conspiracy theories and misperceptions that mislead people about the risks they face and how best to protect themselves. We investigate the effectiveness of interventions aimed at combating false and unsupported information about the Zika epidemic and subsequent yellow fever outbreak in Brazil. Results from a nationally representative survey show that conspiracy theories and other misperceptions about Zika are widely believed. Moreover, results from three preregistered survey experiments suggest that efforts to counter misperceptions about diseases during epidemics and outbreaks may not always be effective. We find that corrective information not only fails to reduce targeted Zika misperceptions but also reduces the accuracy of other beliefs about the disease. In addition, although corrective information about the better-known threat from yellow fever was more effective, none of these corrections affected support for vector control policies or intentions to engage in preventive behavior.

INTRODUCTION

Public health officials struggle to counter false or unsupported claims about health, medicine, and science. These false claims can gain adherents and circulate in public discourse and through social networks despite a lack of scientific evidence to support them (*1*). This problem is especially acute during disease epidemics and outbreaks, when governments must often work to dispel misinformation and build public knowledge around disease control and prevention in the face of a surge of misinformation (*2*, *3*).

Unfortunately, efforts to counter misinformation can have mixed or unintended effects. Although corrective information is often somewhat effective at changing beliefs (*4*), these effects can vary substantially (*5*) and, in some cases, may be counterproductive for beliefs or behavior (*6*). Assessing the effectiveness of efforts to combat misinformation about disease epidemics and outbreaks is thus crucial for public health. There is some evidence that corrective information can reduce false beliefs about diseases under these circumstances, but studies conducted to date often rely on fictional scenarios and/or participants from unaffected countries (*7*, *8*).

A particular challenge in this context is that many public health misperceptions are rooted in conspiracy theories, which attribute events to the secret actions of malevolent, powerful forces that attempt to conceal their role (*9*). These narratives are particularly common during public crises like disease epidemics. For instance, conspiracy beliefs and other forms of misinformation have been a major concern during Ebola outbreaks in West Africa (*10*, *11*), the Zika outbreak in Brazil (*12*), and the recent yellow fever crisis in Brazil (*13*). Conspiracy beliefs often proliferate after unexpected or tragic events like these because they help people explain away or diminish feelings of lack of control, chaos, or uncontrolled risks (*14*). Such effects could be detrimental—exposure to conspiracy theories has been found to reduce people's intentions to take action to protect themselves from communicable disease (*15*). Conspiracy beliefs are thus potentially dangerous during health emergencies if they discourage people from taking preventive action and/or reduce support for policies designed to contain epidemics.

The epidemic of Zika in 2015 and 2016 and subsequent outbreak of yellow fever in 2018 in Brazil illustrate how conspiracy theories about disease can spread despite attempts by governments to correct misinformation. False information circulated widely in the country about the causes of both diseases, the reasons for their spread, and the consequences they could have for human health. Public health officials struggled to combat these claims, which, in some cases, motivated counterproductive policies. For instance, health officials in parts of Brazil banned a pesticide that helped control mosquitoes because it was incorrectly believed to cause microcephaly (*16*).

We examine the prevalence and persistence of misperceptions and conspiracy beliefs during the Zika epidemic and yellow fever outbreak in Brazil. The goal of our study is to see if giving corrective information of the kind that public health campaigns provide to citizens can improve the accuracy of people's beliefs or have other beneficial effects on public attitudes and behavioral intentions. We report two principal findings. First, results from a nationally representative survey demonstrate that Zika misperceptions and conspiracy beliefs were prevalent in Brazil during the epidemic. Second, results from survey experiments conducted there indicate that exposure to corrective information adapted from World Health Organization (WHO) failed to measurably decrease beliefs in targeted myths about Zika, while it unexpectedly decreased the accuracy of other Zika beliefs. Corrective information was more effective in reducing misperceptions about the better-known threat from yellow fever, but it did not measurably increase support for vector control policies or intentions to engage in preventive behavior against mosquitoes for either disease. These results suggest that current approaches to combating conspiracy theories and misperceptions may not be effective and can, in some cases, undermine public understanding of epidemics. Public health officials and other communicators should

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therefore conduct experimental trials to ensure that information campaigns are not counterproductive.

METHODS/OVERVIEW

This article proceeds in two parts. We first report the results of a nationally representative face-to-face survey conducted in Brazil in April and May 2017 to measure the prevalence of Zika misperceptions and conspiracy beliefs. Our results, which were collected while Zika disease transmission was still ongoing and additional Zika-related cases of microcephaly and Guillain-Barre syndrome were being reported (*17*), indicate that most Brazilians understood the role of mosquitoes in spreading Zika and that the virus was not spread by casual contact. However, a distressing number of people endorsed misperceptions that had previously circulated widely in Brazil (often as part of conspiracy theories) blaming the spread of the disease on genetically modified mosquitoes and attributing the surge in microcephaly cases to the use of larvicides in drinking water and to prenatal vaccines (*12*, *18*, *19*).

Second, we report the results of three preregistered survey experiments conducted in 2017 and 2018 on large online samples of Brazilian adults to test the efficacy of public health messages intended to reduce conspiracy theories and misperceptions about Zika (both years) and yellow fever (2018 only). The 2017 Zika experiment examined the effectiveness of public health communications during a disease epidemic in which misinformation was spreading widely. The 2018 Zika experiment was conducted to replicate and extend our initial findings with a broader set of knowledge items, while the 2018 yellow fever study was conducted to determine whether these findings would hold in the context of an outbreak of a better-known disease (see table S1 for an overview of all studies).

The survey and experiments followed all institutional review board guidelines with respect to human subjects and were reviewed by Dartmouth College's Committee for the Protection of Human Subjects (STUDY00029828; approved 19 September 2016, and modified 30 April 2018).

NATIONALLY REPRESENTATIVE SURVEY

Materials and methods

To measure Brazilians' beliefs about Zika, we fielded a module as part of the nationally representative 2017 AmericasBarometer survey. The survey was coordinated and supervised by the Latin American Public Opinion Project, which conducts biannual surveys in 29 countries in the Western Hemisphere. The AmericasBarometer survey drew from a nationally representative sample of voting age adults in Brazil that was stratified by major regions of the country, size of municipality, and urban and rural areas within municipalities. Interviews were conducted face to face at respondent residences by enumerators who used tablet devices to record responses. In total, surveys were conducted with 1532 respondents from 5 April to 11 May 2017. Table S2 summarizes respondent demographics. Our module included questions about the causes and consequences of the Zika outbreak, beliefs in Zika conspiracy theories and misperceptions, support for Zika control policies, preventive behavioral intentions, and perceived threats posed by Zika. To avoid potential social desirability effects, none of these claims were referred to as "conspiracy theories" or "misperceptions" in the survey, which presented them in a neutral fashion (see the Supplementary Materials for exact wording).

Results

Brazilians regarded Zika as a serious threat in 2017—8 in 10 rated the threat it posed to health in Brazil as "high" or "very high." However, the accuracy of their beliefs about the virus varied substantially.

We first measure beliefs about Zika transmission by asking respondents to evaluate the accuracy of three statements—that Zika can be transmitted by mosquitoes (true) and by sexual contact (true) and that it can be transmitted by casual contact (false)—on a four-point scale ranging from "not at all accurate" to "very accurate." Figure 1A summarizes the percentage of respondents who rated each of the three statements as "very accurate" or "somewhat accurate." Our data indicate that 92% of Brazilians endorse the true statement that Zika is spread by mosquitoes, the dominant mode of infection to date. Moreover, 83% of Brazilians know that Zika is not spread by casual contact—only 17% endorsed this false claim as accurate. However, just 40% correctly recognize that Zika can also be spread by sexual contact, a less frequent vector but one that could pose an increased threat to public health once rates of infection are established in the population.

The data also indicate that many Brazilians endorse conspiracy theories and misperceptions regarding Zika that could hinder public health efforts to raise Zika awareness and encourage prevention. More than 63% of respondents indicated that it was "very accurate" or "somewhat accurate" that GMO (genetically modified organism) mosquitoes spread Zika. Slightly more than half also incorrectly endorsed claims attributing the increased prevalence of microcephaly to larvicides and the Tdap vaccine, respectively.

Last, we examine the correlates of these beliefs. Table 1 presents ordinary least squares regression (OLS) models examining the relationship between demographic characteristics (education, income, sex, age, urban residence, and region) and the Zika outcome measures considered earlier: beliefs about possible Zika vectors (columns 1 to 3) and a composite measure of Zika misperception belief (column 4) from items measuring belief that Zika is spread by GMO mosquitoes and that larvicides or the Tdap vaccine caused the increase in microcephaly ($\alpha = 0.57$).

Although most of the estimated effects are small and the variance in Zika-related beliefs accounted for by these factors is limited, we note the following correlations. First, respondents with more years of schooling are less likely to believe that Zika is spread through casual contact and less likely to endorse misperceptions about Zika based on conspiracy theories ($P < 0.005$ in both cases). However, more educated respondents are also less likely to believe that Zika can be transmitted via sexual contact ($P < 0.005$). We also find that respondents from urban areas are less likely to believe, incorrectly, that Zika can be contracted via casual contact ($P < 0.005$). Last, there are also regional differences in responses across Brazil. Perhaps most concerning, in the northeast and southeast—the regions with the highest numbers of documented Zika infections—respondents are more likely to be misinformed about transmission via casual contact ($P < 0.005$ in both cases) and marginally more likely to endorse Zika-related misperceptions ($P < 0.10$ in both cases).

ONLINE SURVEY EXPERIMENTS

To investigate how to counter public health misperceptions and conspiracy theories, we conducted three preregistered, randomized online survey experiments on large samples of Brazilian adults in 2017 and 2018. Specifically, we conducted two experiments examining the effects of corrective information about Zika (in 2017 and

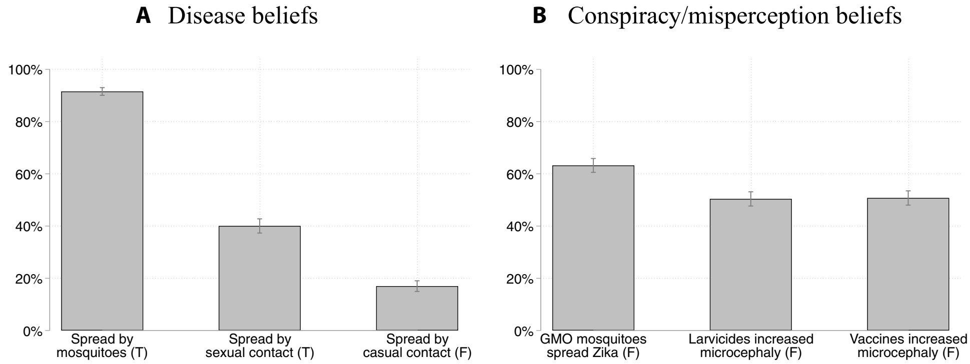

Fig. 1. Zika disease beliefs and conspiracy theory endorsement (representative survey). Means and 95% confidence intervals from the Brazil wave of the 2016 and 2017 AmericasBarometer survey (n = 1532; 5 April to 11 May 2017). "T" and "F" indicate true and false, respectively, for the outcome measures.

2018) and one experiment examining the effects of a similar correction about yellow fever (2018). Both the Zika and yellow fever experiments randomized exposure to disease-specific corrective information adapted from WHO materials. In each experiment, we estimated the effect of exposure to corrective information (relative to a placebo condition) on endorsement of the Zika/yellow fever misperceptions that were specifically debunked in our treatments, on belief in other claims (some factually correct, some incorrect) about Zika/yellow fever, on support for public policies that could prevent the spread of the disease, and on self-reported intention to take steps to protect oneself from the disease. Question wording for all outcome measures is provided in the Supplementary Materials.

Although corrective information can reduce false beliefs, there are also reasons for concern. First, corrections can spur directionally motivated reasoning among people with a predisposition to endorse conspiracy theories (*20*) or among people who believe in the specific misperceptions that are being debunked; for these people, corrections may fail to reduce misperceptions (*21*). Similarly, exposure to false information may, in some cases, produce a so-called continued influence or belief perseverance effect even after the misinformation is definitively corrected (*22*). Introducing false information can increase the familiarity of a false claim and thereby cause it to seem more plausible, especially over time as memory for the truth value of the claims fades (*23*).

Last, unexpected results of the 2017 Zika experiment (discussed below) led us to consider whether corrective messages could undermine people's confidence in other disease-specific beliefs or in their ability to understand scientific issues more generally. Research on meta-cognition demonstrates that people's confidence in the validity of their beliefs affects their openness to persuasion (*24*). These judgments may not always be applied accurately. Research on the so-called tainted truth effect finds that people who are warned about misinformation may overcorrect and become less likely to believe or recall accurate event details (*25*). In addition, efforts to intervene to warn people about the presence of false information can have spillover effects on belief in accurate claims (*26*). (Throughout the article, we use the term "spillover effects" to refer to any impact of corrective interventions on beliefs that are unrelated to the specific corrective information delivered.)

Hypotheses

On the basis of the research discussed above, we test the following hypotheses, which were preregistered in the Evidence in Governance and Politics (EGAP) archive before researcher access to outcome data. All deviations from the preregistered study plan are noted below (URLs omitted for peer review).

First, we test the hypothesis that corrective information about the disease in question will reduce beliefs in targeted myths about the disease and increase the accuracy of respondents' beliefs about these causes and consequences of the disease both immediately (H1a) and after a delay (H1b). If these myths undermine support for policies to prevent the disease in question and reduce behavioral intentions to protect oneself, then corrective information should increase support for policies intended to reduce the spread of the *Aedes aegypti* mosquito (H2), the primary vector for the disease, and increase respondents' intention to protect themselves from mosquito bites (H3). In addition, we test whether the effects of corrective information on belief in myths about the disease in question vary by respondents' pretreatment level of trust in governmental and health institutions (H4a), a factor for which previous studies find differing results (*27*, *28*), and their predisposition to believe in conspiracy theories (H4b).

To evaluate our interpretation of the results of the 2017 Zika experiment, we preregistered additional hypotheses that were formally tested only in the 2018 Zika and yellow fever experiments. These predicted that the myths correction treatment will decrease respondents' belief in factual claims about the disease that are unrelated to the content of the treatment (H5a) and respondents' confidence in their ability to find the truth behind medical and health disputes (H5b).

We also investigate the following research questions for which we have weaker theoretical priors and therefore did not preregister directional hypotheses. First, we consider how a myths correction treatment affects respondents' policy opinions and intended behavior after a delay (RQ1). Second, we examine how the effects of a myths correction treatment on policy opinions and intended behavior vary by respondents' levels of trust and conspiratorial predispositions both immediately and after a delay (RQ2).

Materials and methods

In the 2017 and 2018 Zika experiments and the 2018 yellow fever experiment, we randomized participants into a myths correction treatment condition or into a placebo condition representing the no-information baseline. Using this between-subjects design, we tested the effects of corrective information debunking myths about Zika or yellow fever on the following outcome variables: belief in the myths targeted by corrective information, other disease-related

Table 1. Correlates of Zika beliefs and misperceptions (survey data). *$P < 0.05$, **$P < 0.01$, ***$P < 0.005$ (two-sided); OLS models estimated using survey weights. Data from the Brazil wave of the 2016 and 2017 AmericasBarometer survey (n = 1532; 5 April to 11 May 2017). Outcome variables are measures of factual belief about Zika and a composite measure indicating greater misperceptions about Zika, respectively (see the Supplementary Materials for wording). Respondents ages 16 to 30 are the reference category for age, and the north is the excluded category for region.

	Spreads via mosquito	Spreads via sex	Spread via casual contact	Misperception beliefs (mean)
Years of schooling	0.01	−0.05***	−0.05***	−0.08***
	(0.01)	(0.01)	(0.01)	(0.01)
Moderate income	−0.04	−0.22*	−0.15	−0.05
(quartile 2)	(0.05)	(0.10)	(0.08)	(0.07)
Medium income	−0.01	−0.17	−0.17	−0.16*
(quartile 3)	(0.06)	(0.13)	(0.09)	(0.08)
High income	0.01	−0.25*	−0.14	−0.14
(quartile 4)	(0.06)	(0.11)	(0.08)	(0.08)
Male	0.06	0.00	0.02	−0.13*
	(0.04)	(0.08)	(0.06)	(0.05)
Age 31–45	0.08	−0.07	−0.06	0.03
	(0.04)	(0.08)	(0.06)	(0.06)
Age 46–60	0.00	−0.16	−0.08	−0.09
	(0.06)	(0.11)	(0.07)	(0.08)
Age 61 or older	−0.05	0.07	0.24*	0.05
	(0.08)	(0.14)	(0.11)	(0.09)
Urban	0.06	−0.08	−0.20***	−0.05
	(0.07)	(0.09)	(0.07)	(0.07)
Northeast region	0.03	0.07	0.18***	0.14
	(0.08)	(0.11)	(0.06)	(0.08)
Center-west region	−0.05	0.14	0.16	0.05
	(0.09)	(0.13)	(0.10)	(0.10)
Southeast region	0.02	0.26*	0.20***	0.15
	(0.06)	(0.10)	(0.06)	(0.08)
South region	−0.01	−0.08	0.11	0.03
	(0.08)	(0.13)	(0.07)	(0.09)
Constant	3.53***	2.75***	2.07***	3.31***
	(0.10)	(0.18)	(0.11)	(0.12)
R^2	0.01	0.05	0.07	0.14
n	1402	1331	1391	1284

beliefs, support for policies to prevent the spread of the disease, and intention to engage in preventive behaviors to protect one's self from it.

Our treatments reflect how the WHO and other public health entities communicate information about disease epidemics to affected populations (see the Supplementary Materials for the wording used in the study instruments). The myths correction treatment used in our Zika experiments was adapted from a report issued by the WHO titled "Dispelling rumours around Zika and complications" (http://archive.is/HXd3J). Similarly, the mosquito information and preventive behavior treatments in our Zika experiments were adapted from communication materials released by the Pan American Health Organization for use with the public (http://archive.is/xZpLd and http://archive.is/osYRl). For the 2018 yellow fever experiment, the myths correction information was adapted from reports from the Brazilian Ministry of Health and the fact-checking website AOS Fatos (http://archive.is/cwJoD and http://archive.is/OYI0F).

Last, the 2017 Zika experiment also tested two alternate public health messages that were used by the WHO in Brazil: providing accurate information about the *Aedes aegypti* mosquito, the main carrier of Zika, and describing steps people can take to reduce mosquito breeding in and around their home. Results from these conditions are described in the Supplementary Materials.

Sample composition

The 2017 Zika experiment and the 2018 Zika and yellow fever experiments were administered online to separate convenience samples of Brazilian adults recruited by an opt-in panel of participants maintained by online survey vendor Survey Sampling International.

In the 2017 Zika experiment, data collection occurred in two waves. The first wave, which included our experimental treatments, was fielded from 12 to 24 April 2017 and included 1283 respondents in the myths correction and placebo conditions (n = 616 and n = 667, respectively). These respondents were then recontacted and invited to participate in a second wave of the study, which was fielded from 1 to 30 May 2017 and included the same outcome measures as wave 1. The median interval between responses to waves 1 and 2 among those who participated in both was 17 days. In total, 899 respondents participated in the second wave (recontact rate, 70.6%). Attrition did not vary systematically between conditions (P = 0.16), although wave 2 respondents were significantly older and more educated and more likely to self-identify as white (see table S2 for descriptive statistics on the wave 1 and 2 samples).

The 2018 Zika and yellow fever experiments were conducted from 17 to 31 May 2018. A total of 2173 respondents were randomly assigned to either the Zika experiment or the yellow fever experiment (n = 1081 and n = 1092, respectively). Respondents in each experiment were then randomly assigned to a disease-specific myths correction condition (n = 547 for Zika, n = 501 for yellow fever) or to a placebo condition (n = 534 for Zika, n = 591 for yellow fever).

We note that these experiments were conducted at different points in the life cycles of the two diseases. Zika was a new disease to Brazil when it began to spread in late 2015. Cases of Zika and Google Trends data on searches for information about the disease peaked in Brazil during the first few months of 2016, just over 1 year before our 2017 Zika experiment and 2 years before our 2018 Zika experiment (*29*, *30*). By contrast, yellow fever was a more familiar disease in Brazil but the outbreak was also a more recent experience for participants in our 2018 yellow fever experiment—cases of and search interest in the disease peaked in January and February 2018, just a few months before our study (*31*). The expected effects of these differences in timing on our experiments are not obvious. If beliefs are more firm when an issue is at peak salience, then we might expect our corrective treatments to have less effect on beliefs about yellow fever compared with Zika. Alternatively, if beliefs take root over time, then the relative impact of corrective information might be reversed.

Consistent with other opt-in internet samples, participants in these studies are more white, educated, and wealthy than the Brazilian population (see table S2, which compares the characteristics of the online samples with our representative face-to-face survey sample). However, online convenience samples such as these have been shown to generate experimental treatment effect estimates that closely correspond to those obtained from representative samples (*32*, *33*). Balance tests indicate the experimental randomizations were successful (details available upon request).

Outcome measures

We collected four types of outcome measures in each of our experiments (the exact wording of all questions is provided in the Supplementary Materials). These measures capture belief in misperceptions that were targeted by the corrective information treatment, other beliefs related to the disease or its effects, support for policies intended to reduce the spread of the disease, and self-reported intention to engage in preventive behaviors.

The misperceptions targeted by the myths correction treatment were the same in both the 2017 and 2018 Zika experiments: the beliefs that GMO mosquitoes caused the outbreak and that larvicides or vaccines cause microcephaly. In the yellow fever experiment, the myths correction treatment instead targeted beliefs that the yellow fever vaccine had been rendered ineffective by genetic mutations in the virus, that the vaccine has life-threatening side effects, and that an alternative remedy based on a propolis made by bees provides effective protection against infection. No nationally representative data exist on the prevalence of these myths that is analogous to our Zika survey, but Brazilian and international news sources reported that the misperceptions about yellow fever we tested were being widely circulated online in early 2018 (*13*, *34*, *35*).

As noted above, we also measured other disease-related beliefs that were not targeted by the myths correction treatment. The 2017 Zika experiment measured people's beliefs that Zika can be contracted via mosquito bite (true), by sex (true), and by casual contact (false), and that Zika has potential neurological effects (true). The 2018 Zika experiment not only included these items but also measured beliefs in additional true statements about potential transmission of the virus in utero and via blood transfusion and its connection to microcephaly, as well as false statements about microcephaly causing paralysis and vulnerability to Zika among people with weakened immune systems. The 2018 yellow fever experiment included a similar set of disease-related belief questions. These included belief in true statements that the disease spreads via mosquito bite, that it is spread by the same mosquito as Zika, that its symptoms include fever and vomiting, that the disease can be fatal, that it is now present in cities, and that the government recommends all Brazilians be immunized, as well as belief in incorrect statements that there is no effective vaccine for yellow fever, that the vaccine can cause damage to the immune system, and that the vaccine is a fraud perpetrated by drug companies.

The third set of outcomes measured support for policies intended to reduce the spread of the disease. These were the same in both Zika experiments, which asked respondents about their support for government policies of releasing GMO mosquitoes to limit disease spread, treating water with larvicides, authorizing health officials to enter properties to prevent mosquito-breeding conditions, and recommending the Tdap vaccine. In the yellow fever experiment, we included the first three of these policies and support for fining citizens who do not get vaccinated against yellow fever and for requiring the vaccine for children attending public schools.

The fourth category, preventive intentions, was identical in each experiment. Respondents were asked about their use of long-sleeved shirts and pants, mosquito spray/repellent, and screens or closed windows to keep mosquitoes out.

The items measuring beliefs targeted by the myths correction treatment and other disease-related beliefs are measured on a four-point Likert scale from "not at all accurate" to "very accurate." The policy response items are scored on a 1 (strongly disapprove) to 10 (strongly approve) scale. The behavioral measures are scored on a five-point scale from never (1) to always (5).

Following our preregistration, we conducted principal components factor analysis to examine the extent to which the relevant questions from each set described above constitute reliable scales of targeted misperceptions, other disease-related beliefs, policy support, and preventive intentions. In the first, third, and fourth sets, we found that the items load onto a single factor. In those cases, we create composite indices based on all the items in the group. The questions on other disease-related beliefs, however, do not load onto a single factor, and we therefore analyze responses to each of them separately.

Last, the 2018 Zika and yellow fever experiments measure respondents' beliefs that they can discern the truth about health and science issues, which was adapted from previous research (*36*). The exact wording is provided in the Supplementary Appendix.

Results: 2017 and 2018 Zika experiments

We first present the results of the 2017 and 2018 Zika experiments. Both studies (which use identical designs) estimate the effects of exposure to our myths correction message in a series of OLS regression models with robust standard errors (all reported *P* values are two-sided). However, all results in the main text from the 2017 and 2018 Zika experiments and the 2018 yellow fever experiment are substantively identical when estimated using ordered probit models (see the Supplementary Materials).

We begin by examining the effect of corrective information on endorsement of Zika misperceptions. Table 2 summarizes the effects of the myths correction treatment on the Zika-related misperceptions targeted in both the 2017 and 2018 experiments. The treatment failed to reduce mean belief in these myths significantly in either experiment. In the 2017 experiment, the myths correction treatment had no measurable effect on any of the three mistaken or unsupported claims compared to the placebo condition. Similarly, the 2018 study found that the myths correction treatment had no measurable effect on misperceptions beliefs overall or in specific beliefs that larvicides cause Zika or that vaccines cause microcephaly in the 2018 experiment, although beliefs in GMO mosquito transmission did decline significantly ($P = 0.002$). These findings are precisely estimated; the 95% confidence intervals for the myths correction treatment effects in the experiments exclude even small positive effects on the four-point misperceptions index (2017, −0.08, 0.08; 2018, −0.14, 0.04). H1a is thus not supported.

Exploratory analyses suggest that these null results are not attributable to a lack of respondent attention to the experimental stimuli. The median time respondents spent viewing the information of interest was quite high for an online survey: 54.7 s (2017) and 54.8 s (2018) for the placebo conditions and 57.9 s (2017) and 53.8 s (2018) for the myths correction treatments.

Additional analyses reveal that corrective information is similarly ineffective among respondents who may have differing levels of pretreatment motivation to endorse conspiracy theories. In particular, there is no consistent evidence in either study that the effects of the myths correction treatment vary by respondents' conspiratorial predispositions or trust in governmental and health institutions (H4a and H4b, respectively; see the Supplementary Materials).

Apart from its effects on targeted misperceptions, corrective information might affect other beliefs that respondents hold about the disease in question. Table 3A and fig. S1B indicate that the myths correction treatment unexpectedly reduced the accuracy of respondent's beliefs about two of three true factual claims in the 2017 Zika experiment. Specifically, the perceived accuracy of statements about Zika's neurological effects and the role of mosquitoes in spreading the disease declined ($P < 0.005$ in both cases), although the treatment had no measurable effect on beliefs about Zika being transmitted through sexual contact ($P = 0.60$). In addition, the myths correction treatment decreased the incorrect belief that Zika can be transmitted by casual contact such as a handshake ($P = 0.002$), suggesting that the treatment reduced the perceived accuracy of claims about Zika regardless of whether they are true or untrue. These effects are also jointly significant in an exploratory *F* test of the null hypothesis of no effect on respondent beliefs across these four outcome variables ($P < 0.005$).

In the 2018 Zika experiment, we therefore tested the hypothesis that the myths correction treatment undermines belief in factual claims about the disease more generally (H5a). Our results again indicated that people became less likely to believe in statements about Zika after exposure to the myths correction treatment. These effects were particularly concentrated among accurate statements—exposure to the treatment reduced the accuracy of beliefs about four of six true factual claims but did not move beliefs significantly for any of the three false claims tested. An exploratory *F* test again finds

Table 2. Correction effects on targeted Zika misperceptions. *$P < 0.05$, **$P < 0.01$, ***$P < 0.005$ (two-sided); OLS models with robust standard errors. Respondents are separate samples from Survey Sampling International's online panel in Brazil. For each outcome measure, higher values indicate greater belief in the claim or claims in question [measured on a Likert scale ranging from "not at all accurate" (1) to "very accurate" (4); see the Supplementary Materials for wording]. All outcome measures are false.

	Misperception beliefs (mean)	GMO mosquitoes caused outbreak	Larvicides responsible for microcephaly	Vaccines responsible for microcephaly
A. 2017 Zika experiment				
Myths correction	−0.00	−0.08	0.02	0.07
	(0.04)	(0.06)	(0.05)	(0.05)
Constant	1.69***	1.92***	1.63***	1.53***
	(0.03)	(0.04)	(0.04)	(0.04)
n	1249	1260	1254	1255
B. 2018 Zika experiment				
Myths correction	−0.06	−0.19***	0.01	0.01
	(0.05)	(0.06)	(0.06)	(0.06)
Constant (placebo)	1.68***	1.89***	1.62***	1.55***
	(0.03)	(0.05)	(0.04)	(0.04)
n	1049	1059	1062	1058

Table 3. Correction effects on other Zika beliefs. *$P < 0.05$, **$P < 0.01$, ***$P < 0.005$ (two-sided); OLS models with robust standard errors. Respondents are members of Survey Sampling International's online panel in Brazil. For each outcome measure, higher values indicate greater belief in the claim or claims in question [measured on a Likert scale ranging from "not at all accurate" (1) to "very accurate" (4); see the Supplementary Materials for wording]. "T" and "F" indicate true and false, respectively, for the outcome measures.

(A) 2017 Zika experiment

	Causes neurological problems (T)	Spreads via mosquito bite (T)	Spreads via sexual contact (T)	Spread via casual contact (F)
Myths correction	−0.22***	−0.09***	−0.03	−0.10***
	(0.06)	(0.03)	(0.07)	(0.03)
Constant (placebo)	3.01***	3.85***	1.98***	1.25***
	(0.04)	(0.02)	(0.05)	(0.03)
n	1259	1261	1260	1261

(B) 2018 Zika experiment

	Causes neurological problems (T)	Spreads via mosquito bite (T)	Spreads via sexual contact (T)	Spread via casual contact (F)	Weak immune more vulnerable (F)	Transmit Zika in utero (T)	Zika increases microcephaly (T)	Get Zika from donated blood (T)	Microcephaly causes paralysis (F)
Myths correction	−0.20***	−0.13***	−0.04	−0.04	−0.04	−0.15*	−0.19***	−0.12	−0.10
	(0.06)	(0.04)	(0.07)	(0.04)	(0.07)	(0.06)	(0.04)	(0.07)	(0.06)
Constant (placebo)	3.00***	3.83***	1.86***	1.26***	2.71***	3.37***	3.69***	2.54***	2.82***
	(0.04)	(0.02)	(0.05)	(0.03)	(0.05)	(0.04)	(0.03)	(0.05)	(0.04)
n	1059	1061	1053	1061	1057	1056	1056	1059	1062

that we can reject the null hypothesis of no treatment effect across the nine outcome variables ($P < 0.005$).

Overall, across two Zika experiments, the myths correction treatment measurably decreased belief in 7 of 13 statements about Zika, including 6 of the 9 accurate statements that were tested. All seven remain significant at the $P < 0.05$ level in an exploratory analysis using the Benjamini-Hochberg procedure to control the false discovery rate. Although the magnitude of these effects is modest (Cohen's *d*, 0.15 to 0.27; median, 0.19), the results paradoxically suggest that attempts to rebut misperceptions and conspiracy theories with corrective information actually reduced the accuracy of people's beliefs about the true causes and consequences of Zika.

One interpretation of these results is that people became confused or less certain about what they knew as a result of exposure to the myths correction treatments. Across both Zika experiments, negative spillover effects on respondent knowledge were highly negatively correlated with baseline beliefs. This effect was observed for true statements ($r = -0.55$) but not false ones ($r = -0.03$), a finding that does not appear to be the result of a floor effect.

Why would such an effect occur? Treated respondents do not self-report feeling they are less able to discern the truth about complex health and science issues (H5b; see tables S21 and S29 for results from both the 2018 Zika and yellow fever experiments). Similarly, exploratory analyses also provide no consistent evidence that these effects vary by education or science knowledge (see tables S11 and S20), suggesting that the problem is more complex than a lack of understanding of the scientific information respondents were provided. Another possible interpretation is that respondents who skim the materials learn the gist (that some information about Zika is false) and apply it indiscriminately to other Zika-related beliefs. However, we find no consistent evidence of larger negative spillover effects on respondent knowledge among respondents who completed the pretreatment portion of the survey more quickly or who read the experimental materials more quickly in additional exploratory analyses (see tables S30 and S31).

Our results are instead consistent with a tainted truth effect in which a warning that specific information acquired previously is unreliable can diminish beliefs on related information not addressed in the warning (*25*). Corrections, like warnings, may increase skepticism generally, creating collateral damage to belief in accurate claims and information (*26*). Still, more research is needed to understand the mechanism by which corrective information decreases agreement with true claims, a question we address further in Discussion.

We also examined the effect of the myths correction treatment on respondents' support for public policies intended to prevent Zika (H2) and respondents' intentions to engage in preventive behavior (H3). As table S4 indicates, the treatment failed to significantly affect these outcome measures.

Last, to assess the durability of the effects of the myths correction treatment, the 2017 Zika experiment also surveyed participants after a delay and again measured our outcome variables. While communication effects generally decay over time, one potential concern with informational treatments such as ours is "illusion of truth" effects, which refer to people's tendency to incorrectly remember previously discredited information as true at later points in time (*23*). For instance, while the myths and facts treatment did not have immediate effects on targeted misperceptions, it is possible that this message could have increased familiarity with the targeted claims and therefore increased their credibility at a later point in time. To examine this possibility (H1b), we recontacted respondents in the myths correction and placebo conditions after a delay and measured our outcome variables again. We find that the immediate effect of the myths and facts treatment on factual beliefs disappears after a delay (see table S12). Moreover, we find no significant differences in belief in targeted misperceptions, policy opinions, or behavioral intentions between these groups after a delay. Mirroring the results from wave 1, we also find no evidence that the effect of the myths correction treatment varies with respondents' conspiratorial predispositions or trust in government and health institutions.

Results: 2018 yellow fever experiment

Experimental evaluation of a myths correction treatment on beliefs about yellow fever provided more encouraging results than those obtained for Zika. Table 4 shows the effects of a myths correction treatment on targeted misperceptions (Table 4A) and on factual claims unrelated to those addressed in the treatment (Table 4B). The treatment diminished beliefs in two of the three targeted misperceptions (on the side effects of the vaccine and on the effects of propolis) and reduced overall misperceptions, providing support for H1a. The effect of the myths correction treatment on belief in other factual claims about the disease was weaker and less consistent than observed in the 2017 and 2018 Zika experiments. The yellow fever myths correction treatment increased belief in one of six true claims about the disease—that yellow fever is spread by the same mosquito as Zika—and diminished belief slightly in another—that yellow fever can be fatal. The treatment also diminished belief in one of three false claims—that the vaccine can damage the immune system. Beliefs in six of the nine claims unrelated to the treatment were unaffected. We thus do not find support for H5a. As noted above, H5b was also unsupported (see the Supplementary Materials).

The myths correction treatment had no effect on support for policies intended to reduce the spread of the disease, although intentions to engage in behaviors to protect oneself from yellow fever did increase significantly ($P < 0.05$; see the Supplementary Materials). Last, as in the 2017 and 2018 Zika experiments, we found no evidence that these experimental effects varied by trust in governmental and health institutions or respondents' predisposition to believe in conspiracy theories (H4a/H4b; see the Supplementary Materials).

DISCUSSION

During disease epidemics and outbreaks, public health officials frequently struggle to counter conspiracy theories and misperceptions that discourage citizens from taking preventive action and reduce support for policies designed to contain the spread of disease. This article examines the prevalence and persistence of misperceptions and conspiracy theories in Brazil and reports results from preregistered experiments examining the effectiveness of current approaches to combating false beliefs during the Zika epidemic and subsequent yellow fever outbreak in the country.

Nationally representative survey results from Brazil indicate that the public is only partially informed about Zika and is vulnerable to false or unsupported beliefs. On a more positive note, Brazilians are well informed about whether Zika can be transmitted via mosquito bites and casual contact. However, they have less accurate beliefs about the risks of sexual contact, a less widely discussed mode of transmission. In addition, more than 63% of respondents falsely endorse the myth that GMO mosquitoes spread Zika when asked

Table 4. 2018 yellow fever experiment results. $^*P < 0.05$, $^{**}P < .01$, $^{***}P < .005$ (two-sided); OLS models with robust standard errors. Respondents are members of Survey Sampling International's online panel in Brazil. For each outcome measure, higher values indicate greater belief in the claim or claims in question [measured on a Likert scale ranging from "not at all accurate" (1) to "very accurate" (4); see the Supplementary Materials for wording]. "Misperception belief" is a composite measure calculated as the mean of the three items listed. All misperception measures are false. "T" and "F" indicate true and false, respectively, for the other outcome measures.

(A) Correction effects on targeted yellow fever misperceptions

	Misperception beliefs (mean)	Yellow fever vaccine ineffective	Life-threatening side effects	Propolis protects from yellow fever
Myths correction	−0.20***	−0.03	−0.20***	−0.38***
	(0.04)	(0.06)	(0.06)	(0.06)
Constant (placebo)	1.98***	1.82***	2.00***	2.13***
	(0.03)	(0.04)	(0.04)	(0.04)
n	1063	1072	1072	1075

(B) Correction effects on other yellow fever beliefs

	Spreads via mosquito bite (T)	No effective vaccine (F)	Same mosquito as Zika (T)	Symptoms include fever, vomiting (T)	Disease can be fatal (T)	Government recommends vaccine (T)	Yellow fever in cities (T)	Vaccine causes immune damage (F)	Hoax by drug companies (F)
Myths correction	0.04	0.01	0.36***	0.02	−0.07*	0.11	0.03	−0.14*	0.03
	(0.04)	(0.05)	(0.06)	(0.04)	(0.04)	(0.06)	(0.04)	(0.06)	(0.05)
Constant (placebo)	3.77***	1.55***	3.10***	3.68***	3.82***	3.09***	3.51***	2.01***	1.45***
	(0.03)	(0.03)	(0.05)	(0.02)	(0.02)	(0.04)	(0.03)	(0.04)	(0.03)
n	1068	1077	1070	1075	1073	1073	1073	1074	1068

and more than half incorrectly state that larvicides in water and prenatal vaccines cause microcephaly.

Perhaps most concerning, we find that current approaches to combating misinformation and conspiracy theories about disease epidemics and outbreaks may be ineffective or even counterproductive. In separate experiments in 2017 and 2018, we found that a myths correction message fails to reduce overall belief in the Zika-related misperceptions it targeted. This failure was widespread and occurred among respondents with both high and low motivation to endorse conspiracies. We also found unexpected evidence that the myths correction approach causes collateral damage by reducing belief in other factual claims about Zika that are actually true. The myths correction treatment significantly reduced the perceived accuracy of 7 of 13 factual claims tested in the 2017 and 2018 experiments that were not targeted by the myths correction treatment. In particular, belief in six of nine scientifically accurate facts that we tested declined significantly.

In a separate experiment conducted in 2018 on beliefs related to yellow fever, a myths correction treatment was more effective, decreasing false beliefs overall and for two of three misperceptions that the message debunked. This treatment also inflicted less collateral damage on the accuracy of people's beliefs about the outbreak than the one used in the Zika experiments.

One potential explanation for these differing results is that general knowledge about yellow fever is better established among Brazilians. The disease has been present in the Americas for over a century and has been a longstanding target of public health efforts. By contrast, Zika's first confirmed case in Brazil occurred in 2015. As such, Zika-related beliefs may be less firmly rooted and more vulnerable to spillover effects. This interpretation suggests that the risk of corrective information reducing the accuracy of other disease-related beliefs is lower in situations where baseline knowledge is well established (as with yellow fever in Brazil). By contrast, where public knowledge is less firm, as with Zika (and perhaps other recent epidemics like Ebola), the risk of collateral damage from corrective information to other knowledge may be higher. This distinction is consistent with the differing results from our yellow fever and Zika experiments, but should be tested further in future research, including other contexts besides Brazil.

Our research does have limitations. First, it is possible that social desirability concerns affected responses to our survey measures of misperception belief. We sought to reduce these concerns by avoiding the use of potentially stigmatizing language and conducting our experiment online. Moreover, our findings are not obviously consistent with such an account. Most notably, we found widespread expression of conspiracy belief in our face-to-face survey, where social desirability pressures are likely to be greatest. Nonetheless, future research should consider using experimental designs intended to test for such effects. Second, the linkage between factual beliefs and public policy attitudes is complex and should be explored further. Other values or considerations may be more important determinants of opinion toward policies intended to reduce the spread of Zika and yellow fever. Third, it would be desirable to verify that our experimental results replicate among a representative sample of Brazilians. Last, future research should test whether these results vary with different information sources or formats. We chose not to test such variations because they could reduce our power to detect main effects and also potentially induce heterogeneous treatment effects based on source trust and literacy that are even more difficult to test with appropriate statistical power. Still, source and information format effects should be investigated further in this context.

Despite these limitations, we contribute to the broader literature on misperceptions and conspiracy theory belief in two important respects. First, our findings echo other research showing that efforts to warn people about the presence of false information can have unexpected spillover effects on their belief in other claims (*26*, *37*). In particular, a general warning about the presence of fake news has been found to decrease belief in the accuracy of both false and legitimate news headlines (*26*). Second, these findings demonstrate further evidence that providing accurate factual information does not always have the expected effect on public support for related policies or leaders (*21*).

The knowledge spillover effects we find underscore the need for further randomized controlled trials testing the effects of health messages on attitudinal and behavioral outcomes. Although the Zika epidemic has ended, the study of misperceptions and how to address them has implications for numerous regions and diseases around the world. To prepare for future disease outbreaks, we must know more about the prevalence of conspiracy theories and misperceptions, which types of citizens endorse them, and how to effectively combat them.

Until more is known, however, public health professionals should have realistic expectations about the effectiveness of efforts to provide corrective information during disease outbreaks. It may be more effective to instead pursue alternative strategies that do not involve direct debunking such as educational programs to encourage parents and children to engage with public health information (*38*), participatory approaches that enlist local medical practitioners to disseminate information about disease vectors (*39*), and encouragement of publicly visible prevention and protection measures that might encourage emulation through peer pressure (*40*). In some cases, the best way to defeat misperceptions may be to avoid challenging them directly.

SUPPLEMENTARY MATERIALS

Supplementary material for this article is available at http://advances.sciencemag.org/cgi/content/full/6/5/eaaw7449/DC1

Survey instruments
Additional results
Fig. S1. Beliefs about Zika (experimental data).
Table S1. Study summaries.
Table S2. Sample statistics.
Table S3. Treatment effects on Zika beliefs (experimental data).
Table S4. Treatment effects on Zika attitudes and behavioral intentions.
Table S5. Correction effects in 2017 Zika experiment (ordered probit).
Table S6. Treatment effects on Zika beliefs and attitudes (conspiracy predispositions).
Table S7. Treatment effects on Zika beliefs and attitudes (confidence in government).
Table S8. Treatment effects on Zika beliefs and attitudes (confidence in Ministry of Health).
Table S9. Treatment effects on Zika beliefs and attitudes (confidence in medicine).
Table S10. Treatment effects on Zika beliefs and attitudes (confidence in scientists).
Table S11. Correction effects on other Zika beliefs in 2017 Zika experiment.
Table S12. Correction effects on Zika beliefs and attitudes after delay.
Table S13. Treatment effects on Zika attitudes and behavioral intentions.
Table S14. Correction effects in 2018 Zika experiment (ordered probit).
Table S15. Treatment effects on Zika beliefs and attitudes (conspiracy predispositions).
Table S16. Treatment effects on Zika beliefs and attitudes (confidence in government).
Table S17. Treatment effects on Zika beliefs and attitudes (confidence in Ministry of Health).
Table S18. Treatment effects on Zika beliefs and attitudes (confidence in medicine).
Table S19. Treatment effects on Zika beliefs and attitudes (confidence in scientists).
Table S20. Correction effects on other Zika beliefs in 2018 Zika experiment.
Table S21. Treatment effect on perceived ability to discern truth about health/science.
Table S22. Treatment effects on yellow fever attitudes and behavioral intentions.
Table S23. Correction effects in 2018 yellow fever experiment (ordered probit).
Table S24. Treatment effects on yellow fever beliefs and attitudes (conspiracy predispositions).
Table S25. Treatment effects on yellow fever beliefs and attitudes (confidence in government).

Table S26. Treatment effects on yellow fever beliefs and attitudes (confidence in Ministry of Health).
Table S27. Treatment effects on yellow fever beliefs and attitudes (confidence in medicine).
Table S28. Treatment effects on yellow fever beliefs and attitudes (confidence in scientists).
Table S29. Treatment effect on perceived ability to discern truth about health/science.
Table S30. Correction effects on other Zika beliefs by pre-experiment response time.
Table S31. Correction effects on other Zika beliefs by experimental response time.
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