Intentions to use a novel Zika vaccine: the effects of misbeliefs about the MMR vaccine and perceptions about Zika

Yotam Ophir[1], Kathleen Hall Jamieson[2]

[1]The Annenberg School for Communication, University of Pennsylvania, Philadelphia, PA, USA
[2]The Annenberg Public Policy Center, University of Pennsylvania, Philadelphia, PA, USA
Address correspondence to Yotam Ophir, E-mail: yophir@asc.upenn.edu

ABSTRACT

Background People's intentions to use vaccines are influenced by their beliefs about both the specific vaccine and the disease it prevents. In the absence of firm beliefs about Zika virus (ZIKV), individuals may base their intentions to vaccinate against it on beliefs about other vaccines, and specifically the misbelief that MMR causes autism.

Methods A survey of 3337 Americans, using a random-digit-dialing sample of landline telephone households and cell-phones.

Results Intentions to use a Zika vaccine were influenced by beliefs about Zika, science in general, and MMR. Intentions were positively influenced by perceived severity of and vulnerability to Zika, as well as belief in science's efficacy. However, intentions were negatively influenced by the belief that MMR causes autism in children.

Conclusion The misbelief about MMR and autism may reduce people's intentions to use a new Zika vaccine. However, perceptions of severity of and vulnerability to Zika may increase intentions. Implications for science educators and public health officials are discussed.

Keywords beliefs, communicable diseases, immunization

Introduction

When deciding whether to vaccinate, people weigh the potential risks tied to both the vaccine and the disease. The risks associated with Zika are consequential. The fetus of an infected mother bears an increased risk of birth defects including microcephaly.[1–3] Moreover, in adults, Zika is associated, albeit rarely, with Guillain-Barré syndrome.[4–6] As of February 2018, there had been 228 cases of presumed local mosquito-borne transmissions within the United States, and a total of 5658 cases (with the majority of cases the result of travelers returning from affected areas). Overall, 37175 additional cases had been reported in US territories, a figure largely attributable to widespread exposure in Puerto Rico.[7]

In August 2016, the National Institutes of Health (NIH) announced the launch of a Phase 1 clinical trial of a DNA-based vaccine.[8] The second phase of the trial of that vaccine was announced on 31 March 2017.[9] Understanding the conditions that inhibit or increase acceptance of such a new vaccine should be a public health imperative. In the absence of a realistic understanding of the risks of Zika and the benefits and risks of a Zika vaccine, people may import into the decision process their beliefs or misbeliefs about other vaccines. Using a phone-based survey ($n = 3337$), this study examines the factors affecting people's intentions to get a Zika vaccine, including the misbelief about an association between the Measles, Mumps and Rubella (MMR) vaccine and autism, and discusses implications for public health practitioners and communicators.

From beliefs about vaccines to behavior—a reasoned action approach

Despite incontrovertible benefits,[10] vaccinations have been the subject of misinformation about alleged risks.[11,12] Resulting

Yotam Ophir, Ph.D. Candidate
Kathleen Hall Jamieson, Director

misbeliefs can attenuate vaccination rates, risking a resurgence in diseases considered under control.[13] One enduring deception avers that the MMR vaccine causes autism.[14] The bogus association was convincingly debunked in research studies,[15] and the original paper by Wakefield and colleagues was exposed as biased, error-ridden and contaminated by unethical practices. Subsequently, Wakefield's British medical license was revoked and the paper retracted.[16–18] Nevertheless, many continue to embrace the discredited association.[19] A 2014 Harris online Poll of 1756 US adults found that 33% of parents of children under the age of 18, and 29% of adults reported believing that 'vaccinations can cause autism'.[20] A 2015 survey of 1000 US adults by YouGov, found 21% of young adults accepting the notion that vaccines cause autism; 13% of all US adults agreed.[21]

MMR misbeliefs correlate with reduced intentions to vaccinate children,[22] a relationship forecast by the model underlying the Theory of Reasoned Action, TRA.[23,24] In this theory the strongest predictor of volitional behavior is behavioral intentions,[25] resulting from beliefs, attitudes and norms, and in later models, perceived control[26]. The model is empirically supported.[27,28] Like other theories of health decision making, such as the Health Belief Model[29] and the Protection Motivation Theory,[30] TRA predicts relationships between specific, and not general, constructs.[31] For example, more positive attitudes toward drug-abuse were found to be correlated with actual use of drugs ($r = 0.46$, $P < 0.01$) and to a lesser degree with alcohol use ($r = 0.29$, $P < 0.05$)[32]. Similarly, a meta-analysis[28] demonstrated that moderately relevant attitudes and beliefs may influence intentions and behaviors. Hence, we expect intentions to vaccinate against Zika to be strongly correlated with beliefs about Zika and its vaccine, and to a lesser degree with beliefs about other vaccines and diseases, and other health behaviors.[28]

Nevertheless, information about new diseases is often incomplete, and individuals may form beliefs based on those already held about familiar diseases and treatments.[33] Previous Zika outbreaks did not attract much scientific or public attention, as most cases resulted in few, if any, noticeable symptoms or mild ones.[34–38] It was only in 2015[37] that the disease was found to correlate with microcephaly,[1,38,39] and, in adults, with Guillain-Barré syndrome (GBS).[4,5] As Zika vaccines are being developed and tested,[40,41] the scientific understanding of the nature of the virus remains incomplete and the public's knowledge of what science does know lagging. Just as attitudes toward drugs can correlate with alcohol drinking behavior,[32] intentions to use a Zika vaccine might be influenced by extrapolations from other vaccines.[25] Accordingly, we hypothesized that:

*H*1: The more likely a person is to believe that MMR can cause neurological disorders such as autism, the less likely she will be to intend to use a Zika vaccine if available.

Although less compatible with the behavior than vaccine beliefs,[25] general beliefs about science may also influence intentions to use a vaccine developed by the scientific community:

*H*2: People who believe in science's power to overcome problems will be more likely to intend to use a Zika vaccine than will those who believe that science is less efficacious.

Finally, since people are more likely to reject vaccines if they believe the diseases they protect against pose little risk[12,42] and since individuals are more likely to act to prevent a specific disease when they believe themselves to be susceptible to it,[29] we hypothesize that:

*H*3: There will be a positive correlation between people's intention to get a Zika vaccine, if available, and (i) their beliefs that Zika is dangerous to themselves and to children, and (ii) their belief that they are highly vulnerable to infection by Zika.

Methods

Sample and survey design

Data were collected between 08/25/16 and 09/26/16 (The data analyzed are part of a larger project, a 34-week-long survey with updated and replaced questions that consisted of 37193 participants. The questions relevant and needed for the analysis were used only on some dates, limiting the sample to 3337 participants after a listwise-deletion process.), as part of a national US survey about Zika. Samples were drawn to represent the adult US population (SSRS Omnibus surveys insert weights to provide nationally representative and projectable estimates of the adult population, 18 years and older. As is often the case in large-scale surveys, some variables may still vary somewhat from census data. In our case, education is skewed a bit towards higher levels. We control for that by using demographic variables in the regression model. We do not, however, use weights in the regression model itself, as unweighted OLS estimates are considered unbiased and consistent, and have smaller standard errors compared to weighted OLS estimates. For more on that decision, consult Winship and Radbill.[43] For a detailed information about SSRS's Omnibus survey, see: http://ssrs.com/wp-content/uploads/2017/11/SSRS-Omnibus-Methodology-November-2017.pdf) and used a fully replicated, single-stage, random-digit-dialing (RDD) sample of landline telephone households and cell-phones. Within each landline household, a single respondent (youngest adult) was selected and, for cell-phone respondents, interviews were conducted with the person answering the phone. Approximately 35 interviews were conducted weekly in Spanish. The sample consisted of 3337 people (1713 females, 2305 whites) between the ages of 18 and 97 (M = 52.76, SD = 19.05). Response rate was 9%. Table 1 presents more sociodemographic information on the sample.

Measures

Due to the questionnaire's breadth, constructs were measured using single items. Intention to vaccinate against Zika was measured using the item 'If there were a vaccine that protected you from getting ZIKA how likely, if at all, is it that you would get the vaccine?', ranging from 1 (not likely at all) to 4 (very likely). The misbelief about MMR was measured using the item 'How likely do you think it is that vaccines given to children for diseases like measles, mumps and rubella can cause neurological disorders like autism?', ranging from 1 (not likely at all) to 4 (very likely).

Table 1 Sociodemographic characteristics of the study's sample

Variable	*Frequency*	*%*
Age		
18–39	898	27.0
40–59	1068	32.0
60+	1371	41.0
Ethnicity		
White	2305	69.0
Hispanic	382	11.4
Black	361	10.8
Asian	55	1.6
Native-American	46	1.3
Other/Mixed	188	5.9
Education		
Less than high school	207	6.2
High school	659	19.7
Some college/college graduates	1732	52.0
Some professional or post-graduate (no degrees)	90	2.7
Professional or post-graduate degrees	649	19.4
Income		
Less than 100 K a year	2269	68.0
More than 100 K a year	782	32.0
Religion		
Christian	2713	81.3
Atheist/agnostic	161	4.8
Other	463	13.9

Perceived severity of Zika was measured using the items 'How likely is it that someone who contracts the ZIKA virus will die as a result?', 'How likely, if at all, is it that a baby born with an unusually small head, as a result of ZIKA virus, will die prematurely as a result?', both ranging from 1 (not likely at all) to 4 (very likely) and 'How accurate is it to say that a pregnant woman who is infected with the Zika virus is more likely to have a baby with an unusually small head and brain?', ranging from 1 (not at all accurate) to 4 (very accurate). Perceived vulnerability was measured using the item 'What is the risk that you will be infected with Zika in the next 6 months?', ranging from 1 (no risk), to 5 (extremely high risk).

Belief in science's efficacy was measured using an item from Bolsen *et al.*:[44] 'Which comes closer to your view: science enables us to overcome almost any problem or that science creates unintended consequences and replaces older problems with new ones?', with three possible options ('science enables us to overcome almost any problem', 'science creates unintended consequences and replaces older problems with new ones', and 'somewhere in between/it depends/a bit of both').

Other covariances included the questions 'If you planned a trip before you knew about the ZIKA virus, how likely would it be for you to change your travel plans if you learned that your destination had an outbreak of the ZIKA virus?', ranging from 1 (not likely at all) to 4 (very likely), 'have you gone to any source online or offline to learn more about the ZIKA virus, or not?' (yes/no), how likely it is to say that mosquitoes can transmit the Zika virus to humans', and 'How accurate is it to say that an individual who has been infected by the ZIKA virus will know it because the ZIKA virus always produces noticeable symptoms?', 'both ranging from 1 (not at all accurate) to 4 (very accurate), 'Just your best guess, how many cases have there been in the United States in the last 6 months in which a baby with an unusually small head and brain has been born to a mother who had the ZIKA virus while she was pregnant?', and 'In the past 3 months, have you done anything to protect yourself from getting Zika?' (yes/no). Finally, three covariates measured general attitudes toward the governmental institutions that are responsible for fighting Zika, 'How confident, if at all, are you in the federal government's ability to respond effectively to an outbreak of Zika virus in the United States?', ranging from 1 (not confident at all) to 4 (very confident), and what 'is your general opinion' of the CDC, and NIH, from 1 (very unfavorable) to 4 (very favorable).

Results

Descriptive statistics

On average, intentions to vaccinate against Zika if a vaccine becomes available registered 2.52 (1.17) and beliefs that

MMR may cause autism 2.12(1.00), both measured on 1–4 scales. The bivariate correlation between the misbelief and intention to vaccinate was negative, small and significant ($r = -0.12$, $P < 0.001$). Intention was higher among those lowest on the misbelief ($M = 2.70$, SD = 0.16) and lowest among those highest on the misbelief ($M = 2.3$, SD = 0.13). Intentions also correlated with perceived severity, as the correlation of intention with the mistaken belief that Zika is a likely cause of death was moderately positive ($r = 0.18$, $P <$ 0.001), and a smaller positive correlation was found with the belief that Zika causes microcephaly ($r = 0.10$, $P < 0.001$). Intentions also correlated with the perception that one is likely to be infected in the upcoming 6 months ($r = 0.18$, P < 0.001).

In order to examine the demographic characteristics of those who believed that MMR causes autism, a multiple regression was conducted. People aged 40–59 were more likely to believe the misinformation than were those 18–39 ($\beta = 0.07$, $P < 0.001$. The difference for people older than 60 was not significant ($\beta = 0.02$, $P = 0.30$). Whites, the biggest racial group in the sample, were less likely to believe in the misinformation than non-whites ($\beta = -0.15$, $P < 0.001$). Those who were college educated (college degree or higher) were less likely to believe in the misinformation than non-graduates ($\beta = -0.15$, $P < 0.001$). People with yearly household incomes higher than $100,000 were less likely to believe in the misinformation than those of lower income ($\beta = -0.07$, $P < 0.001$). Atheists were less likely than religious people to believe in the misinformation ($\beta = -0.08$, $P < 0.001$). Finally, people who identified as Democrats were less likely to embrace the misinformation than Republicans ($\beta = -0.10$, $P < 0.001$). Gender did not predict misbeliefs. These variables explained 9% of the variance in the misbelief. Full regression results can be seen in Table 3 in the Appendix.

Hypotheses testing

To test the hypotheses, a multiple regression was conducted. Because no effect was found for the date of the survey, participants were analyzed together. The model explained 20.2% of the variance (adjusted R^2). H1 predicted that belief that MMR can cause neurological disorders such as autism will be associated with lesser intent to use a Zika vaccine. Controlling for all other variables in the model, the effect of the misbelief on intentions was negative, and significant ($\beta =$ -0.019, $P < 0.001$). The misbelief was the strongest predictor of intention not to vaccinate in the model. Thus, H1 was supported.

H2 predicted that people who believe in science's ability to overcome problems will be more likely to intend to use a Zika vaccine than people who believe that science is not efficacious. Controlling for all other variables in the model, the effect of the belief in science's efficacy on intentions was positive and significant. On average, people who believed that science is efficacious were more likely to intend to vaccinate than were those who believed the opposite ($\beta = 0.10$, $P < 0.001$), or fell between the two belief extremes ($\beta =$ 0.05, $P < 0.001$). H2 was also supported.

H3 predicted a positive correlation between vaccination intention and (i) beliefs that Zika is dangerous, and (ii) belief that the respondent is highly likely to be infected with Zika. Controlling for other variables in the model, the effect of the mistaken belief that Zika is likely to cause death ($\beta =$ 0.12, $P < 0.001$) and the accurate belief that Zika causes microcephaly ($\beta = 0.05$, $P < 0.001$) were positive and significant. The belief that microcephaly may lead to the death of newborns did not predict intentions and was omitted from the final model. H3a was generally supported. The effects of the belief that one will be infected in the next 6 months on intention was positive and significant ($\beta = 0.15$, $P < 0.001$), supporting H3b.

As for covariates, younger people (18–39) were higher on intentions to vaccinate. than people aged 40–59 ($\beta = 0.06$, $P < 0.001$) and over 60 ($\beta = 0.04$, $P = 0.001$). People with a college degree (or more years of education) were less likely than those with less than a college degree to intend to vaccinate ($\beta = -0.03$, $P = 0.025$). Democrats' intentions were higher on average than Republicans' ($\beta = 0.04$, $P = 0.029$). Looking for information about Zika online was associated with increased intentions ($\beta = 0.06$, $P < 0.001$), as was knowing that Zika can be acquired from mosquitoes ($\beta =$ 0.05, $P < 0.001$). Mistakenly believing infected people always show symptoms increased intentions ($\beta = 0.05$, $P = 0.001$). Also, the more cases of microcephaly people believed were diagnosed in the US, the higher their intentions were ($\beta =$ 0.03, $P = 0.021$). People who reported having taken action to reduce the risk of infection were lower on intentions ($\beta =$ -0.08, $P < 0.001$). Finally, general positive opinions about the CDC ($\beta = 0.05$, $P = 0.003$) and NIH ($\beta = 0.06$, $P =$ 0.001) increased intentions, as well as confidence in the government's response ($\beta = 0.05$, $P = 0.002$). The full regression results can be seen in Table 2 (We also tested a more parsimonious model with only the misblief and demographics. Conclusions regarding the association of the misbelief and intentions remained virtually the same. The two models can be seen in Table 2.).

Table 2 Summary of multiple regression analysis of intentions to use a Zika vaccine

Variable	*Model I*				*Model II*			
	B	*SE*	β	t-*value*	B	*SE*	β	t-*value*
Constant	2.96***	0.04	0	63.82	0.84***	0.17	0	4.87
MMR-autism	−0.16***	0.01	−0.14	−11.32	−0.22***	0.02	−0.19	−11.13
Age (40–59)	−0.15***	0.03	−0.05	−3.97	−0.16***	0.04	−0.07	−3.56
Age (60+)	−0.13***	0.03	−0.05	−3.54	−0.12*	0.04	−0.05	−2.65
Race (non-White)	0.30***	0.03	0.11	9.17	0.18***	0.03	0.07	5.31
Education (college Graduate or higher)	−0.10***	0.03	−0.04	−3.53	−0.08*	0.03	−0.03	−2.23
Political party (Democrat)					0.10*	0.04	0.04	2.17
Living in Florida					0.08*	0.03	−0.03	−2.07
Science efficacy (low)					−0.23***	0.03	−0.10	−5.96
Learning online					−0.15***	0.04	−0.06	−3.68
Infection from mosquito					0.07***	0.02	0.05	3.48
Always showing symptoms					0.06**	0.02	0.05	3.25
Number of US cases					0.07*	0.03	0.03	2.29
Act to protect					−0.20***	0.03	−0.08	−5.18
Opinion CDC					0.08**	0.03	0.05	2.88
Opinion NIH					0.09**	0.02	0.06	3.17
Confidence in government response					0.06**	0.02	0.05	2.97
Change trip					0.14***	0.01	0.14	8.64
Sample size	5597				3337			
Adjusted R^2	0.035				0.202			

Note. *$P < 0.05$, **$P < 0.01$, ***$P < 0.001$. A full description of items can be seen in the Appendix. The descriptive information in Table 1 corresponds to the sample used in Model II.

Discussion

This study examined the effects of beliefs on intention to use a potential Zika vaccine, and found that people's intentions increased as perceptions of severity of the disease and personal vulnerability increased. People's belief in science's efficacy also increased intentions. However, the misbelief that MMR causes autism in children reduced intentions and was its strongest predictor. These findings are worrisome, but can guide future vaccination communications. On one hand, because the effect of a decades'-old misleading argument on medical and scientific endeavors persists, MMR misbeliefs can reduce intentions to vaccinate against Zika. On the other hand, perceived severity of and vulnerability to Zika may increase vaccination intentions, especially when the risk to adults is highlighted (some perceptions, like the lethality of Zika are inaccurate and require future corrections, but others were correct).

Interestingly, individuals who engaged in behaviors that protect against Zika infection were lower on vaccination intentions. This may be the result of their confidence that their actions pre-empt the need to be vaccinated. Those communicating about the vaccine should consider explaining its effectiveness above and beyond individual actions. These potential interventions are consistent with theories of health behavior and decision making, that predict that perception that a threat is severe and the respondent vulnerable increases the likelihood of responsive action.

This study has both practical and theoretical implications. As the Zika vaccine is being developed, health communicators will soon need not only to cope with vaccine hesitancy and anti-vaccination communications but also with the other challenges involved in delivering vaccinations to vulnerable populations. Building on prior research and theories about health decision making, this study emphasizes the importance of risk perceptions, including severity and susceptibility. To scholarship supporting the importance of a match among attitudes, beliefs and intentions, this study adds evidence of the need for health communicators to address a spill-over effect from misbeliefs about one vaccine on intention to use another.

We note several caveats regarding findings. First, the use of single-item measurements for the dependent and independent variables, and the covariates that produce statistical noise may mask some of the effects or suppress their sizes. Nonetheless, the effects were significant. Second, the data used for analysis is cross-sectional and thus cannot be interpreted as causal. For example, it may be the case that individuals who intended to get the vaccine sought more information online. However, this caveat would not apply to the main variables of interest, misbeliefs about MMR and perceived severity and vulnerability. Finally, the variance explained in the intentions to vaccinate was relatively small (R^2 = 19.81%), a possible product of statistical noise attributable to the single-item measurements, or to the absence of other TRA components from the model, such as attitudes and perceived control. Factors not measured here that may also diminish intentions to vaccinate include the fact that the vaccine is new, and fears associated with the possible desirability of vaccinating pregnant women. Future studies should more comprehensively test the range of attitudinal barriers to vaccination and the specific ways in which they may affect intentions.

Supplementary data

Supplementary data are available at the *Journal of Public Health* online.

Funding

The study was funded by the Science of Science Communication endowment of the Annenberg Public Policy Center of the University of Pennsylvania.

Acknowledgements

The authors wish to thank Dr Kenneth Winneg for his help in designing and conducting the survey. The study was approved by the Institutional Review Board (IRB) of the University of Pennsylvania.

References

1 Rubin EJ, Greene MF, Baden LR. Zika virus and microcephaly. *N Engl J Med* 2016;**374**(**10**):984–5.

2 Honein MA *et al.* Birth defects among fetuses and infants of US women with evidence of possible Zika virus infection during pregnancy. *J Am Med Assoc* 2017;**317**(**1**):59–68.

3 Reynolds MR *et al.* Vital signs: update on Zika virus-associated birth defects and evaluation of all U.S. infants with congenital Zika virus exposure—U.S. Zika Pregnancy Registry, 2016. *MMWR Morb Mortal Wkly Rep* 2017;**66**(**13**):366–73.

4 Cao-Lormeau V-M *et al.* Guillain-Barré syndrome outbreak associated with Zika virus infection in French Polynesia: a case-control study. *Lancet* 2016;**387**(**10027**):1531–9.

5 Winer JB. Guillain Barré syndrome. *Mol Pathol* 2001;**54**(**6**):381–5.

6 Centers for Disease Control and Prevention (CDC). *Zika and Guillain-Barré Syndrome*. [Online]. http://www.cdc.gov/zika/healtheffects/gbs-qa.html. (6 January 2017, date last accessed).

7 Centers for Disease Control and Prevention (CDC). *Case Counts in the US*. [Online]. http://www.cdc.gov/zika/geo/united-states.html. (26 February 2018, date last accessed).

8 National Institute of Health (NIH). *NIH Begins Testing Investigational Zika Vaccine in Humans*. [Online]. http://www.nih.gov/news-events/news-releases/nih-begins-testing-investigational-zika-vaccine-humans. (6 January 2017, date last accessed).

9 National Institute of Allery and Infectious Diseases. *Phase 2 Zika Vaccine Trial Begins in U.S., Central and South America | NIH: National Institute of Allergy and Infectious Diseases*. [Online]. https://www.niaid.nih.gov/news-events/phase-2-zika-vaccine-trial-begins-us-central-and-south-america. (19 April 2017, date last accessed).

10 Offit PA. *Vaccinated: One Man's Quest to Defeat the World's Deadliest Diseases*. New York, NY: Harper Collins, 2009.

11 Jolley D, Douglas KM. The effects of anti-vaccine conspiracy theories on vaccination intentions. *PLoS One* 2014;**9**(**2**):e89177.

12 Kata A. A postmodern Pandora's box: anti-vaccination misinformation on the Internet. *Vaccine* 2010;**28**(**7**):1709–16.

13 Broniatowski DA, Hilyard KM, Dredze M. Effective vaccine communication during the disneyland measles outbreak. *Vaccine* 2016;**34** (**28**):3225–8.

14 Baker JP. Mercury, vaccines, and autism. *Am J Public Health* 2008;**98** (**2**):244–53.

15 Taylor LE, Swerdfeger AL, Eslick GD. Vaccines are not associated with autism: an evidence-based meta-analysis of case-control and cohort studies. *Vaccine* 2014;**32**(**29**):3623–9.

16 Gerber JS, Offit PA. Vaccines and autism: a tale of shifting hypotheses. *Clinical Infectious Diseases* 2009;**48**(**4**):456–61.

17 Offit PA. *Autism's False Prophets: Bad Science, Risky Medicine, and the Search for a Cure*. Columbia University Press, 2010.

18 Deer B. How the case against the MMR vaccine was fixed. *Br Med J* 2011;**342**:c5347.

19 Freed GL, Clark SJ, Butchart AT *et al.* Parental vaccine safety concerns in 2009. *Pediatrics* 2010;**125**(**4**):654–9.

20 National Consumer League Communications. Survey: One third of American parents mistakenly link vaccines to autism. *National Consumers League*. [Online]. http://www.nclnet.org/survey_one_third_of_american_parents_mistakenly_link_vaccines_to_autism. (17 April 2017, date last accessed).

21 YouGov | Young Americans most worried about vaccines. *YouGov: What the World Thinks*. [Online]. Available at: https://today.yougov.com/news/2015/01/30/young-americans-worried-vaccines/. (17 April 2017, date last accessed).

22 Betsch C, Renkewitz F, Betsch T *et al.* The influence of vaccine-critical websites on perceiving vaccination risks. *J Health Psychol* 2010;**15**(**3**):446–55.

23 Ajzen I, Fishbein M. Attitude-behavior relations: a theoretical analysis and review of empirical research. *Psychol Bull* 1977;**84**(**5**):888–918.

24 Fishbein M, Ajzen I. Attitudes and opinions. *Annu Rev Psychol* 1972: 487–544.

25 Hale JL, Householder BJ, Greene KL. The theory of reasoned action. In: *The Persuasion Handbook: Developments in Theory and Practice*, 2002.

26 Ajzen I. From intentions to actions: a theory of planned behavior. In: Kuhl PDJ, Beckmann DJ (Eds.). *Action Control*. Berlin, Heidelberg: Springer, 1985, 11–39.

27 Godin G, Kok G. The theory of planned behavior: a review of its applications to health-related behaviors. *Am J Health Promot* 1996;**11** (**2**):87–98.

28 Kim M-S, Hunter JE. Attitude-behavior relations: a meta-analysis of attitudinal relevance and topic. *J Commun* 1993;**43**(**1**):101–42.

29 Rosenstock IM. Historical origins of the health belief model. *Health Educ Behav* 1974;**2**(**4**):328–35.

30 Rogers RW. A protection motivation theory of fear appeals and attitude change1. *J Psychol* 1975;**91**(**1**):93–114.

31 Fishbein M, Yzer MC. Using theory to design effective health behavior interventions. *Commun Theory* 2003;**13**(**2**):164–83.

32 Jones JW. Attitudinal correlates of employees' deviance: theft, alcohol use, and nonprescribed drug use. *Psychol Rep* 1980;**47**(**1**):71–7.

33 Stephenson T. *Swine Flu H1N1: The Facts*. London, UK and Philadelphia, US: Jessica Kingsley, 2009.

34 Driggers RW *et al*. Zika virus infection with prolonged maternal viremia and fetal brain abnormalities. *N Engl J Med* 2016;**374**(**22**):2142–51.

35 Hennessey M, Fischer M, Staples JE. Zika virus spreads to new areas—region of the Americas, May 2015–January 2016. *Am J Transplant* 2016;**16**(**3**):1031–4.

36 Centers for Disease Control and Prevention (CDC). *Symptoms*. [Online]. http://www.cdc.gov/zika/symptoms/symptoms.html. (6 January 2017, date last accessed).

37 Rasmussen SA, Jamieson DJ, Honein MA *et al*. Zika virus and birth defects—reviewing the evidence for causality. *N Engl J Med* 2016; **374**(**20**):1981–7.

38 França GVA *et al*. Congenital Zika virus syndrome in Brazil: a case series of the first 1501 livebirths with complete investigation. *Lancet* 2016;**388**(**10047**):891–7.

39 Garcez PP *et al*. Zika virus impairs growth in human neurospheres and brain organoids. *Science* 2016;**352**(**6287**):816–8.

40 Dyer O. Zika vaccine could be in production by year's end, says maker. *Br Med J* 2016;**352**:i630.

41 Anderson KB, Thomas SJ, Endy TP. The emergence of Zika virus: a narrative review. *Ann Intern Med* 2016;**165**(**3**):175–83.

42 Smailbegovic MS, Laing GJ, Bedford H. Why do parents decide against immunization? The effect of health beliefs and health professionals. *Child Care Health Dev* 2003;**29**(**4**):303–11.

43 Winship C, Radbill L. Sampling weights and regression analysis. *Sociol Methods Res* 1994;**23**(**2**):230–57.

44 Bolsen T, Druckman JN, Cook FL. How frames can undermine support for scientific adaptations: politicization and the status-quo bias. *Public Opin Q* 2014;**78**(**1**):1–26.