The European Journal of Public Health Advance Access published August 21, 2015

European Journal of Public Health, 1–4

doi:10.1093/eurpub/ckv154

Detrimental effects of introducing partial compulsory vaccination: experimental evidence

Cornelia Betsch,[1] Robert Böhm[2]

1 Department of Psychology and Center for Empirical Research in Economics and Behavioral Sciences (CEREB), University of Erfurt, Erfurt, Germany
2 School of Business and Economics, RWTH Aachen University, Aachen, Germany

Correspondence: Cornelia Betsch, University of Erfurt, Nordhäuser Str. 63, 99089 Erfurt, Germany, Tel: +49 361 737 1631, Fax: +49 361 737 2209, e-mail: cornelia.betsch@uni-erfurt.de

Background: During outbreaks of vaccine-preventable diseases, compulsory vaccination is sometimes discussed as a last resort to counter vaccine refusal. Besides ethical arguments, however, empirical evidence on the consequences of making selected vaccinations compulsory is lacking. Such evidence is needed to make informed public health decisions. This study therefore assesses the effect of partial compulsory vaccination on the uptake of other voluntary vaccines. **Method:** A total of 297 (*N*) participants took part in an online experiment that simulated two sequential vaccination decisions using an incentivized behavioural vaccination game. The game framework bases on epidemiological, psychological and game-theoretical models of vaccination. Participants were randomized to the compulsory vaccination intervention ($n = 144$) or voluntary vaccination control group ($n = 153$), which determined the decision architecture of the first of two decisions. The critical second decision was voluntary for all participants. We also assessed the level of anger, vaccination attitude and perceived severity of the two diseases. **Results:** Compulsory vaccination increased the level of anger among individuals with a rather negative vaccination attitude, whereas voluntary vaccination did not. This led to a decrease in vaccination uptake by 39% in the second voluntary vaccination (reactance). **Conclusion:** Making only selected vaccinations compulsory can have detrimental effects on the vaccination programme by decreasing the uptake of voluntary vaccinations. As this effect occurred especially for vaccine hesitant participants, the prevalence of vaccine hesitancy within a society will influence the damage of partial compulsory vaccination.

Introduction

Vaccine hesitancy globally jeopardizes public health and the attainment of disease elimination goals.[1] Individuals with a negative attitude towards vaccination frequently opt-out of vaccine programmes and refuse vaccination,[2,3] creating pockets of susceptible individuals who facilitate outbreaks of vaccine-preventable diseases, e.g. of measles in Germany, France and Austria in 2015. Such outbreaks often create public debates about partial compulsory vaccination, mostly focusing on some selective vaccinations such as measles, mumps and rubella. Additionally, the discovery of new and effective vaccines, such as against the human papilloma virus, can instigate debates about making a vaccine mandatory.[4] Advocates of compulsory vaccination emphasize a child's right to receive the best possible health care, the community's right to be protected from vaccine-preventable diseases by means of herd immunity or healthcare workers' duty to protect potentially immune-compromised patients.[5–7] Advocates of voluntary vaccination, on the contrary, underline the right of parents to rear their children according to their own standards, the fact that compulsory vaccination undermines people's bodily integrity and autonomy, as well as the principle of non-maleficence.[8] Moreover, neglecting the social benefit of vaccination, the individual risk of infection is usually small, which, in the view of some scholars, ethically prohibits compulsory vaccination.[9]

Most of the debate rests upon this ethical argumentation. The goal of this contribution is to add empirical evidence on the potential sequel of introducing partial compulsory vaccination. Partial compulsory vaccination means that the law requires only a subset of the generally recommended vaccinations to be implemented, while the rest remains voluntary. Building on psychological work on reactance, we assess externalities of compulsory vaccination on voluntary vaccination decisions. Previous work has shown that interventions that decrease the freedom of choice can result in reactance, i.e. the motivation to reassert a constricted freedom.[10] Thus, we can expect that if individuals feel constricted, i.e. because they have a negative attitude towards vaccination and did not intrinsically intend to vaccinate, they will reassert their freedom of choice by refusing vaccination on the next possible occasion. Thus, paradoxically, the introduction of partial compulsory vaccination can backfire especially there where it is needed most: among people who have a negative attitude towards vaccination. The following study tests these considerations.

Methods

To test the potential externalities of a partial compulsory vaccination on other voluntary vaccinations, we conducted an incentive-compatible online experiment using a behavioural vaccination game. The game setting allows observing behavior instead of relying only on behavioural intentions, a situation which increases internal and external validity. In a sequential order, participants faced two scenarios, in both of which they could contract an infectious disease and vaccination was possible. In the first situation, participants were randomly assigned either to an intervention or to a control group. In the intervention group, vaccination was compulsory. In the control group, vaccination was voluntary. In the second situation, vaccination was voluntary for all participants. Our main objective was to investigate the effect of the decision architecture of the first decision (compulsory vs. voluntary) on vaccine uptake in the second decision, depending on subjective properties of the participants (vaccination attitude, reactance due to compulsory vaccination).

Participants

Participants were $N = 297$ students (59.9% female; $M_{age} = 23.11$, $SD_{age} = 3.86$) from various academic disciplines of two German universities. The experimental set-up followed the ethical guidelines of the German Research Foundation, the German Psychological Society and the American Psychological Association. All participants gave their written informed consent to participate voluntarily, and they were assured that all statistical analyses and reports would be anonymous. Decisions were incentivized: after the experiment, 20 participants were randomly selected for payment applying a random-lottery incentive scheme. Every participant had the same chance to be selected. The exact amount depended on their decisions and the respective payoff in the experiment (payments from 5 to 10 Euro, $M = 7.55$ Euro; see next section).

Vaccination decisions

Building on epidemiological, game-theoretical and psychological models of vaccination behaviour,[11–13] we used a vaccination framework that considers both the direct and indirect effects of vaccinations (see Supplementary Material for details on the behavioural vaccination game). The game was played for two rounds. In each round, participants were endowed with 100 'fitness points' (exchange rate: 100 points = 10 Euro) and could lose 50 points due to an infection if they had not been vaccinated but could also lose 20 points due to side effects if they had been vaccinated. Vaccination always yields fixed costs of 10 points, which, for example, represent the pain from the needle prick or waiting time in a doctor's office. The Supplementary Material provides the exact game parameters. The disease parameters (R0, severity of the symptoms) as well as the associated risks and benefits from vaccination were the same in the first and the second vaccination decision. Because of the indirect protection from herd immunity, the probability of infection decreased as a function of the individuals already vaccinated in the population, i.e. the vaccination rate among all study participants. This probability is therefore unknown to participants at the time of their decision making. In contrast, the probability of side effects was fixed, known to participants and independent of others' vaccination decisions. In other words, the game represented the realistic situation where—potentially costly—vaccination protects the individual her-/himself but also other people due to herd immunity.[5]

Additional measures

As a proxy for reactance, we assessed the level of anger,[14] represented by the mean of ratings of how angry, irritated and annoyed participants felt after the first vaccination decision (ratings on scales ranging from 1 = *not at all* to 7 = *very much*, Cronbach's alpha = 0.87). Mean level of anger was $M = 2.14$, SD = 1.45. The general attitude of participants towards vaccination was assessed with a 7-point scale from 1 = *totally against vaccinations* to 7 = *totally in favour of vaccinations*. Mean attitude was $M = 5.40$ SD = 1.42. Furthermore, participants were asked about the relative perceived severity of the first disease compared with the second disease (lower, equal or higher).

Results

We perform a moderated mediation regression analysis[15] with the second vaccination decision as the binary dependent variable and the decision architecture of the first vaccination decision (intervention vs. control) as the independent variable (table 1). Level of anger serves as the mediator variable between previous choice architecture and decision, and the vaccination attitude (mean centred) is included as the moderator variable of this relation. Furthermore, we control for participants' age and gender. In a first step, there is a significant interaction effect of treatment and vaccination attitude on anger. Individuals with a relatively negative vaccination attitude felt angry after being forced to vaccinate [simple slope: $B = 1.32$, SE = 0.22, 95% bootstrapped bias-corrected confidence interval (BC CI) (0.87, 1.76), figure 1: continuous line]. This effect is much weaker and not significant for individuals with a positive vaccination attitude [simple slope: $B = 0.30$, SE = 0.22, 95% BC CI (−0.13, 0.74); figure 1: dashed line]. In other words, compulsory vaccination increased the level of anger among those individuals with a rather negative vaccination attitude, whereas voluntary vaccination did not.

In a second step, we test whether this may cause reactance by decreasing vaccination uptake in the second decision. Indeed, the conditional indirect effect from treatment via level of anger on vaccination decision is significant for individuals with a negative vaccination attitude, decreasing vaccine uptake significantly by 39%. In contrast, the decrease explained by reactance is only about 8% and not significantly different from zero for individuals with a positive vaccination attitude (table 1). Thus, vaccination uptake in the second vaccination decision decreased when the first vaccination was compulsory (vs. voluntary) among individuals with a rather negative vaccination attitude. As a consequence, in the control group, vaccine uptake among individuals with a positive vaccination attitude was about 38% higher than among individuals with a negative vaccination attitude. In contrast, in the intervention group, this difference was 53%.

As an alternative explanation, we test whether a disease with compulsory vaccination is perceived to be more severe compared with a disease with voluntary vaccination and whether this difference in perceived severity may cause decreased voluntary vaccine uptake for the disease that is perceived as less severe. In fact, 41% of the participants in the intervention group perceived the first disease to be more severe than the second one, whereas only 4% did so in the control group. However, there is no effect of perceived severity on vaccination decision [$B = -0.09$, SE = 0.26, 95% BC CI (−0.60, 0.43), controlling for treatment, age and gender]. Hence, we reject this alternative explanation.

Discussion

A recent review concludes that introducing compulsory vaccination in hospitals is a successful strategy in raising vaccination rates of health care personnel to >90%.[16] Only one of the studies that were included in the review, however, additionally assessed attitudinal variables.[17] Despite high vaccination rates, 72% of these participants agreed that compulsory vaccination was a coercive measure.[17] Importantly, none of the studies assessed the externalities of partial compulsory vaccination on other voluntary vaccinations. This experiment's data suggest that especially for individuals with a rather negative attitude towards vaccination, partial compulsory vaccination can have detrimental effects on the uptake of other voluntary vaccinations. Thus, making selected vaccinations compulsory is likely to increase the uptake of this particular vaccine. However, the overall effect on vaccine uptake in a society—or a smaller setting such as a hospital—can be negative.

The increased level of anger among vaccine hesitant individuals supports the interpretation that compulsory vaccination can lead to reactance, i.e. the wish to regain the constricted freedom of choice. As an alternative explanation of the effect, we excluded the possibility that the perceived difference in severity of the disease with and without compulsory vaccination drives the effect. Risk homoeostasis theory[18] posits that once one risk is mitigated (e.g. by compulsory vaccination), individuals are inclined to more risky behaviour on another occasion, keeping the overall level of risk in homoeostasis. Accordingly, individuals who perceive a rather low overall-level of risk from vaccine-preventable diseases may feel the urge to regain homoeostasis by refusing the second voluntary vaccination. Future studies should take this additional explanation into account, especially with focusing on the question if individuals with a

Table 1 Multiple regression analysis: moderated mediation

	Mediator variable model (outcome: level of anger)			
Predictor	***B***	**SE**	**95% BC CI**	
Constant	2.93	0.59	(1.77, 4.10)	
Treatment	0.81	0.16	(0.50, 1.12)	
Vacc. attitude	−0.29	0.05	(−0.40, −0.19)	
Treatment * vacc. attitude	−0.36	0.11	(−0.58, −0.14)	
Age	−0.01	0.02	(−0.05, 0.03)	
Gender	−0.28	0.16	(−0.60, 0.04)	
	Dependent variable model (outcome: vaccination decision)			
Predictor	***B***	**SE**	**95% BC CI**	**Odds ratio**
Constant	0.20	0.95	(−1.67, 2.07)	
Treatment	0.25	0.26	(−0.26, 0.76)	1.28
Level of anger	−0.25	0.09	(−0.42, −0.08)	0.78
Age	−0.01	0.03	(−0.06, 0.06)	0.99
Gender	0.57	0.26	(0.07, 1.07)	1.76
	Conditional indirect effects of treatment via level of anger on vaccination decision at values ± 1 SD of the moderator			
Moderator condition	***B***	**SE**	**95% BC CI**	**Odds ratio**
− 1 SD vacc. attitude	−0.33	0.16	(−0.68, −0.08)	0.72
+ 1 SD vacc. attitude	−0.08	0.06	(−0.24, 0.01)	0.92

Treatment: 0 = control group, 1 = intervention group. Vaccination decision: 0 = non-vaccination, 1 = vaccination. Gender: 0 = female, 1 = male. 95% BC CI: bootstrapped bias-corrected confidence intervals (10 000 iterations). Mediator variable model is based on OLS regression, and dependent variable model is based on logistic regression.

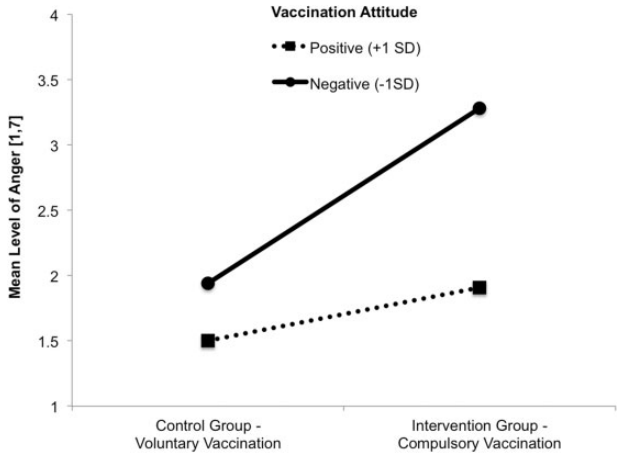

Figure 1 Simple slopes: Influence of treatment on level of anger, depending on the attitude towards vaccination. Note: Individuals with a relatively negative vaccination attitude felt angry after being forced to vaccinate [simple slope: $B = 1.32$, SE = 0.22, 95% BC CI (0.87, 1.76), continuous line]. This effect is much weaker and not significant for individuals with a positive vaccination attitude [simple slope: $B = 0.30$, SE = 0.22, 95% BC CI (−0.13, 0.74); dashed line].

rather negative attitude towards vaccination also perceive lower levels of threat by vaccine-preventable diseases.

This study had several limitations, for instance a sample showing a relatively positive attitude towards vaccination and relatively low levels of anger. This may have led to an underestimation of the effects that occur outside the game context. The student sample fits the topic at hand, as in Germany partial compulsory vaccination for measles was discussed and there are considerable immunity gaps regarding measles in young adults.[19] Nevertheless, the study should be replicated with a representative sample to ensure generalizability of the results. Additionally, a behavioural game is not a perfect representation of real vaccine decision making, even though its structure implements incentives that are known to have a major impact on real-life decision making (such as potential side-effects of the vaccine, positive externalities of vaccination on others via herd immunity). Besides calculating risks and benefits, factors like convenience, complacency and confidence in vaccines and health organizations may further play an additional role in real-life decisions.[20]

Overall, we conclude that the prevalence of vaccine hesitancy in a society determines the potential effect of partial compulsory vaccinations on that society's vaccine programme. Specifically, introducing compulsory vaccination into programmes that also contain voluntary vaccinations may backfire by causing substantial reactance among individuals with negative vaccination attitudes. This eventually may cause strong damage in societies which have high levels of vaccine hesitancy, i.e. large proportions of individuals who have a negative attitude (e.g. France[21]). The monitoring of vaccine hesitancy and vaccine-related perceptions and attitudes can take place via (social) media[22,23] as well as by means of easy-to-use questionnaire tools in representative surveys (examples for questions and scope as well as a comprehensive overview, see Ref. 22. Regularly monitoring the distribution of attitudes towards vaccination in the population is crucial to wisely apply regulative measures and advocacy procedures and thus to avoid potential detrimental effects on voluntary vaccinations.

Supplementary data

Supplementary data are available at *EURPUB* online.

Acknowledgements

The authors had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

Conflicts of Interest: Cornelia Betsch is a member of the European Technical Advisory Group of Experts in Immunization (ETAGE, WHO Euro) and of the German Verification Committee for Measles and Rubella Elimination. She has received honoraria from GlaxoSmithKline for non-product-related talks.

Key points

- This study provides quantitative evidence on the influence of partial compulsory vaccination on the success of a vaccine program
- The presence of partial compulsory vaccination lowers uptake of voluntary vaccinations especially among individuals with a negative attitude towards vaccination
- Compulsory vaccination can lead to reactance, i.e. the wish to regain the constricted freedom of choice. This was especially prominent among individuals with a negative attitude towards vaccination
- Regularly monitoring the distribution of attitudes towards vaccination in the population is strongly advised to wisely apply regulative public health measures and advocacy procedures

References

1 WHO. *SAGE Working Group on Vaccine Hesitancy—Literature Review*. Geneva: World Health Organization, 2013.

2 Opel DJ, Taylor JA, Zhou C, et al. The relationship between parent attitudes about childhood vaccines survey scores and future child immunization status: a validation study. *JAMA Pediatr* 2013;167:1065–71.

3 Lindley MC, Wortley PM, Winston CA, Bardenheier BH. The role of attitudes in understanding disparities in adult influenza vaccination. *Am J Prev Med* 2006;31:281–5.

4 Roll CA. Human papillomavirus vaccine: should it be mandatory or voluntary. *J Health Care Law Policy* 2007;10:616–622.

5 Fine P, Eames K, Heymann DL. ''Herd immunity'': a rough guide. *Clin Infect Dis* 2011;52:911–6.

6 Ciolli A. Mandatory school vaccinations: the role of tort law. *Yale J Biol Med* 2008;81:129–37.

7 Galanakis E, Jansen A, Lopalco P, Giesecke J. Ethics of mandatory vaccination for healthcare workers. *Euro Surveill* 2013;18:20627.

8 Hooper CR, Breathnach A, Iqbal R. Is there a case for mandating influenza vaccination in healthcare workers? *Anaesthesia* 2014;69:95–100.

9 Bradley P. Should childhood immunisation be compulsory? *J Med Ethics* 1999;25:330–4.

10 Bensley LS, Wu R. The role of psychological reactance in drinking following alcohol prevention messages. *J Appl Soc Psychol* 1991;21:1111–24.

11 Betsch C, Böhm R, Korn L. Inviting free-riders or appealing to prosocial behaviour? Game-theoretical reflections on communicating herd immunity in vaccine advocacy. *Health Psychol* 2013;32:978–85.

12 Bauch CT, Earn DJD. Vaccination and the theory of games. *Proc Natl Acad Sci U S A* 2004;101:13391–4.

13 Ibuka Y, Li M, Vietri J, et al. Free-riding behaviour in vaccination decisions: an experimental study. *PLoS One* 2014;9:e87164.

14 Dillard JP, Shen L. On the nature of reactance and its role in persuasive health communication. *Commun Monogr* 2005;72:144–68.

15 Hayes AF. *Introduction to Mediation, Moderation, and Conditional Process Analysis: A Regression-Based Approach*. New York, NY: Guilford Press, 2013.

16 Pitts SI, Maruthur NM, Millar KR, et al. A systematic review of mandatory influenza vaccination in healthcare personnel. *Am J Prev Med* 2014;47:330–40.

17 Feemster KA, Prasad P, Smith MJ, et al. Employee designation and health care worker support of an influenza vaccine mandate at a large pediatric tertiary care hospital. *Vaccine* 2011;29:1762–9.

18 Wilde GJS. Risk homeostasis theory: an overview. *Inj Prev* 1998;4:89–91.

19 Takla A, Wichmann O, Rieck T, Matysiak-Klose D. Measles incidence and reporting trends in Germany, 2007–2011. *Bull World Health Organ* 2014;92:742–9.

20 Betsch C, Böhm R, Chapman GB. Using Behavioral Insights to Increase Vaccination Policy Effectiveness. *Policy Insights from the Behavioral and Brain Sciences in press*.

21 Peretti-Watel P, Verger P, Raude J, et al. Dramatic change in public attitudes towards vaccination during the 2009 influenza A(H1N1) pandemic in France. *Euro Surveill* 2013;18:20623.

22 Larson HJ, Jarrett C, Schulz W, et al. Measuring vaccine hesitancy: the development of a survey tool. *Vaccine* 2015 pii: S0264-410X(15)00501-0. doi: 10.1016/j.vaccine.2015.04.037. [Epub ahead of print].

23 Larson HJ, Smith DMD, Paterson P, et al. Measuring vaccine confidence: analysis of data obtained by a media surveillance system used to analyse public concerns about vaccines. *Lancet Infect Dis* 2013;13:606–13.