Int J Public Health (2012) 57:333–340
DOI 10.1007/s00038-011-0326-9

ORIGINAL ARTICLE

Similarity of parents and physicians in the decision to vaccinate children against measles, mumps and rubella

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Received: 7 September 2010 / Revised: 22 November 2011 / Accepted: 29 November 2011 / Published online: 16 December 2011

Abstract
Objectives This study investigates parental decisions to vaccinate their children against measles, mumps and rubella (MMR). Parent and provider survey data allow the analysis of interactions between these major players in decision making.
Methods Three datasets are used for analysis: (a) the basic population of the school entry-level health checkup in Munich, Germany; (b) a face-to-face survey with parents of children taking the school entry-level health checkup; (c) a face-to-face survey of the physicians treating these children. Logistic, OLS and multilevel regressions were applied.
Results Homophily due to similar ages of parents and physicians boosts the decision to vaccinate children against MMR. Also in relation to parent–physician interaction, the fact that a physician may be homeopathic has no effect on a parents' decision to immunize, although vaccination-skeptical parents choose physicians who are trained in homeopathy.
Conclusions Efforts to improve the number of parental decisions for vaccination should focus on the educational level of the parents as well as homophily of parents and physicians. Notably, homogeneity of parents and providers concerning age changes decisions in favor of vaccinating.

Keywords MMR · Vaccination behavior · Parent–physician interaction · Multilevel analysis

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Introduction

High vaccination coverage for measles and other diseases can be achieved in countries without compulsory regulations only if a sufficient number of parents agree to vaccinate their children. The vaccination rate for measles in Germany in 2008 was 95.9% for the first dose and 89.0% for the second, according to entry-level checkup data collected for all German school children by the Robert Koch Institute (2010). These rates are still not high enough to eradicate the illness, as this would require 95% coverage in each region nationwide (Robert Koch Institute 1999; Meissner et al. 2004). Some regions in Germany show lower coverage, e.g., Bavaria (93.4% for the first dose and 84.7% for the second). This article investigates parental decisions to vaccinate their children against measles, mumps and rubella (MMR) and the role of physicians in influencing these decisions.

Several studies have investigated the determinants of parents' decision to vaccinate as well as their knowledge of vaccines (Borràs et al. 2009; Casiday 2007; Gust et al. 2004, 2005; Kennedy et al. 2005; Skea et al. 2008). Some studies have examined the role of religious beliefs (Kennedy and Gust 2008), while others investigated the behavior of migrant populations (Mikolajczyk et al. 2008). Other works have linked decisions to virus circulation and community size (Keeling and Grenfell 1997) and mathematical aspects of the basic reproduction number (Hethcote 2000; Farrington et al. 2001). Outbreaks of measles still occur in various areas (Richard and Masserey Spicher 2009; Hahné et al. 2010; Jansen et al. 2003).

Theoretical considerations concerning vaccination decision making often cite educational influences. The production efficiency hypothesis (Becker 1965, 1995) states that education generally results in better outcomes

(Grossman 2000). The probability of parents vaccinating their children increases with parental education, according to this view. So far, this mechanism has been confirmed for primary school children (Vandermeulen et al. 2008). This argument is only convincing if one assumes preferences are constant across similarly educated parents. But distrust in complementary and alternative medicine and other vaccination-related beliefs may induce skepticism about the merits of immunization, resulting in insufficient coverage (Jones et al. 2010). Trust in homeopathy is a crucial factor, especially for MMR vaccination (English 1995). The preference of parents (Sporton and Francis 2001) and physicians (Lehrke et al. 2001) for homeopathy or other alternative medicines may negatively affect vaccination coverage. It is also important to consider the influence of physicians on parental decision making. Even the purported effects of education on vaccination habits are not valid if parents are influenced by the advice of physicians. But physician influence may be overstated if the researcher does not adequately model selection effects. Parents do not select their physicians at random; they choose doctors they like or with whom they share similar attitudes. "Similarity breeds connection" as the principle of homophily states (McPherson et al. 2001). A possible signal (Spence 1973) of opposition to vaccination is selection of a homeopathic physician.

This project seeks to explain why parents chose (or do not chose) to vaccinate their children against MMR, while controlling for the potential selection effects that arise from parents' choice of physician. Other studies of this nature examine parent and provider data independently, but this does not allow one to address selection bias. This shortcoming is overcome by the "Munich Vaccination Study", which was funded by the German Research Foundation (DFG) over a period of 2 years (JU 414/2-1). The study's major innovation is the joint analysis of three datasets. The first dataset comes from a mandatory entry-level health checkup of Munich school children (Germany, 2000). Physicians record information from children's national or international vaccination logs. This information reliably indicates whether or not the child has been immunized against MMR. This data was used as the dependent variable for parental and physician surveys conducted in 2001. Parents are nested "within" physicians, so multilevel analysis is the appropriate statistical method for analyzing these data.

Methods

Study design

Due to the need to combine parent and physician surveys, the data for this study had to be collected in a relatively small region. We selected Munich (the capital of the German state of Bavaria) because the city's immunization rate (87.6% in 2000) (own calculations) is considerably lower than the national average (91% in 2000) (Reiter and Rasch 2004). A lower immunization rate provides greater variation in the dependent variable, making it easier to test explanatory models. The Munich Ministry of Health and Environment supported the project and granted access to the school entry-level health checkup data.

The first database is the school entry-level health checkup of all first graders in Munich for the year 2000 (process generated data). In this year, about 9,800 children entered first grade and 9,270 saw doctors in time for the survey (the checkups were compulsory). Observations were missing either because parents did not have a Munich address at the time the invitations for checkups were issued (the children of these parents would receive checkups the following year) or the final checkups were not completed in time for inclusion in the dataset. It is unlikely vaccination behavior is correlated with the decision to move to Munich at a certain time of year. Selection bias due to late checkups is also unlikely, since scheduling decisions were not made by parents. Thus, the data are broadly representative of the population. The data were collected using TELEform Elite—a common software package for collecting and verifying (medical) data (Newswire 2011)— and a Cannon DR-3020 scanner. The use of these sophisticated technologies provides additional assurance that the data are of high quality. Figure 1 provides a schematic depiction of the research design, and includes information on the number of cases in each dataset.

The health checkup data provides information on children's height and weight, their physicians' names and previous illnesses and vaccinations, as provided by each child's national or international vaccination log. Thus, school doctors can easily tell which children have been immunized. However, values were missing for 1,004 children whose parents forgot to bring their vaccination logs to the checkups. Non-German parents and parents with three or more children were less likely to provide their logs. There were also 766 children who received only one or two of the three vaccinations. These cases do not provide a firm position for or against vaccination and it is difficult to examine this complex decision quantitatively. Thus, these observations were dropped from the sample.

The second dataset consists of survey data collected through face-to-face interviews with children's parents (2001). Parents were informed that the University of Munich was conducting a survey and were asked to release their addresses in order to participate. Of the 7,000 parents contacted, 3,083 (44%) approved the use of their addresses. This group represents the basis of the sample. The characteristics of participants were compared to the entire

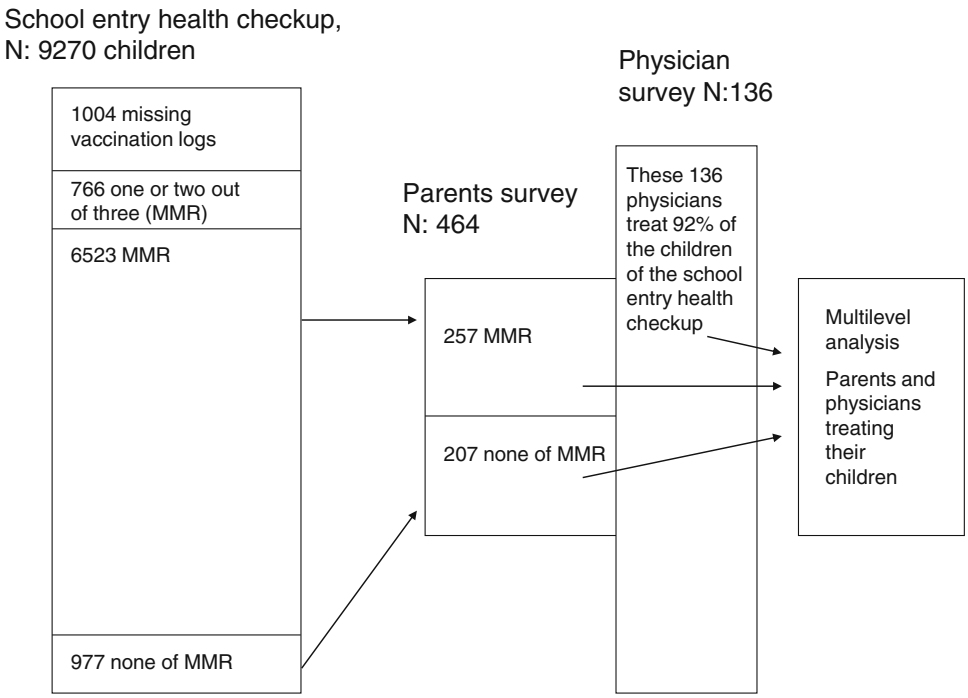

Fig. 1 The study design and number of cases of the three datasets, Munich Vaccination Study 2001

population of first graders. Sample characteristics did not differ from the rest of the population in terms of gender, but there is a bias related to nationality. Of the 9,270 cases, 27.7% were non-German, but only 11.4% of non-Germans released their addresses for participation. As much as 22.8% of the children had not been vaccinated against MMR, while 18.8% of the parents who provided their addresses had not vaccinated their children. (Observations with missing vaccination logs are valid values in this case.) Thus, the selection bias from releasing addresses for study participation is low.

A simple probability sample would have over-sampled the parents of vaccinated children. Therefore, a disproportional design was used. Parents with children immunized against MMR represent one layer and parents of children with none of these vaccinations represent the other.

A sample of 791 cases was selected randomly within these layers. Adjusted for neutral non-response (e.g., wrong addresses), the number falls to 671 cases. A total of 464 parents participated for a participation rate of 69%. The interviews were conducted by 22 professional interviewers. Willingness to participate was not correlated with parents' decision to immunize their children. A weight adjusts the data proportions according to the sampling population. According to the health checkup data (there were 7,500 valid values according to the vaccination log) the weight for parents without immunized children was (977/7,500)/(207/464) = 0.29, and for parents with immunized children was (6,523/7,500)/(257/464) = 1.57.

Predominantly mothers participated in the study. Only 16 men participated, making it impossible to analyze the effects of parental gender. Parents were asked for the name of their physicians after MMR vaccinations had been given. About 50% of the parents changed their physicians between childbirth and the interview. Therefore, other physicians may have administered the injections. But the vaccination rate was 54.5% for parents who never changed their doctors and 58.6% for parents who changed their physicians (result unweighted). The difference in proportions between these groups was not statistically significant ($\chi^2 = 0.73$). In addition to the parental survey, a face-to-face survey of physicians was also conducted in 2001. The basic population was the doctors who treated the children at the school entry-level health checkup. In Munich, there were 141 registered pediatricians, 612 internists and 515 general practitioners (in the year 2000). The lion's share of the children was treated by pediatricians, with only a few being treated by internists or general practitioners.

The sampling procedure for physicians was not intended to be representative at the level of physicians, but at the level of treatment, since it is the physicians who treat children that are most likely to influence parental decisions. Accordingly, the physicians who treat the most children had the highest probability of being sampled. A total of 342 different doctors treated the 9,270 children at the entry-level checkup. The physician with the most children had 82. His probability of being selected was "1". The sampling probability for other physicians declined with the number of their treatments. A total of 201 physicians were sampled, but 10 could not be found due to wrong addresses, lowering the sample to 191 cases; 136 physicians participated for a response rate of 71%. These 136

physicians treated 92% of all first graders in Munich in the year 2000.

It is generally difficult to interview physicians. But the German Association of Pediatricians supported the survey and the association's senior-most representative provided an endorsement letter in the invitation to participate. This letter of endorsement was probably the main determinant of the high response rate.

The sampling procedure necessitates a weighted model of physicians' impact. The mean number of children treated by each physician was 15.88, so the weight is the number of children in the care of one physician/15.88. The lowest weight, for a physician who treats just one child, is 0.06 and the highest weight is 4.91 for the doctor with the highest number of treatments (78 children).

Independent and dependent variables

One measurement issue should be stressed: the dependent variable, whether or not a child is vaccinated against MMR, is derived from children's vaccination log and not from the parental survey. The school doctors ascertained whether children were vaccinated from the type of vaccine and the injection dates reported in the logs. These logs provide a much more accurate measure of vaccination rates than parental surveys, since parents often do not remember which vaccinations their children had received. The correlation between physician data and parents' beliefs about their children's vaccination status was only 0.4 (own calculations).

To measure parental attitudes toward scientific medicine, a four-point scale was used, with the most favorable attitudes attributed to parents who agreed with the statement that "In case of illness only scientific medicine is acceptable" and the least favorable attitudes attributed to parents who agreed that "Naturopathy is generally better than scientific medicine". This scale was transformed into a dichotomous variable for the purpose of multilevel analysis, with values less than 3 taking a value of 1 and values greater than or equal to 3 taking a value of 0. Respondents were also asked how important organic food was to their health promotion. This variable was measured on a five-point scale, with the highest score reserved for those with the most favorable attitudes toward organic foods (5 = 1, 1–4 = 0). A four-point scale was used to measure parents' views on the dangers of illness related to MMR (additive index). The distance to the physician was measured by the time, in minutes, that it took to travel to the medical office (one way).

Independent variables in the physician survey are age measured in years, the type of medical office, the average length of consultation time, the volume of vaccination literature in the office and the doctor's background in homeopathy. In Germany, a joint medical office is defined as physicians working as a team, sharing responsibility for a group of patients and creating joint business volume. By contrast, a group medical office is defined as physicians sharing rent and medical secretaries, but creating individual business volume. Physicians were asked to estimate the average number of minutes spent discussing the pros and cons of vaccinations with parents. Interviewers measured the volume of vaccination literature by counting the number of different brochures and posters related to MMR in waiting rooms (range 0–10). Interviewers also collected data on the homeopathic preferences of doctors by looking for references to degrees in homeopathy on physicians' signboards. Physicians received a score of 1 if they held a degree in homeopathy and a score of 0 if they did not.

Statistical methods

Parental choice takes a value of 1 if the child is immunized against MMR and a value of 0 if the child is not. The discrete nature of the outcome lends itself to a binary choice model. Accordingly, a binary logit model is adopted. The dependent variable for the physician sample is the physician's individual vaccination rate. If, for example, a doctor treats 15 children and 14 are vaccinated, the variable takes a value of 0.93. This variable ranges from 0 to 1 with a mean of 0.76. The continuous nature of the variable calls for OLS estimation.

A third analysis employs a hierarchical linear model (HLM) to estimate parent and provider influences simultaneously. All variables in the multilevel analysis are grand mean centered. Population-average models (Neuhaus et al. 1991) with robust standard errors using parent and physician weights are reported here. The models include fixed effects, because random coefficients do not convey additional information.

Three types of models were estimated. MDM 1 uses only variables from the parent survey controlling for physician selection. MDM 2 uses both parental and physician variables simultaneously and MDM 3 adds the cross-level effect. Only one cross-level effect is tested, because variation on both variables (parental and physician) is needed. There is little variation in terms of parental gender (almost all participants were women) and no variation in physician education (all physicians possess a university degree). Only the age variable provides enough variation to permit the testing of a cross-level interaction.

All model assumptions were tested, including the linearity of effects. The efficiency of estimates is not harmed by multicollinearity or heteroscedasticity; VIF statistics and standardized residuals (+leverage) show normal patterns. DFbetas were used to test for outliers, but none were found (all values were $<|0.4|$).

Results

Overall, younger parents tend to support MMR vaccinations more than older ones, as shown in Table 1. Education is negatively correlated with vaccination behavior.

Children of parents who believe in the use of scientific medicine are much more likely to be immunized than children whose parents endorse homeopathy or/and naturopathy. Parents preferring organic food are also less likely to vaccinate their children.

Parents worried about the dangers associated with MMR are also much more likely to vaccinate their children. The distance in minutes between a child's home and the physician's office negatively affects vaccination rates. Of parents with children immunized against MMR, 22% choose doctors trained in homeopathy, but 61% of parents who refuse MMR prefer doctors with a degree in alternative medicine (not shown in Table 1). Often, these doctors are not located in nearby neighborhoods, and so the distance to the doctor's office is great (see Table 1).

Table 2 shows the results of the physician survey: older physicians are more successful at persuading parents to vaccinate their children. The type of medical office is also important: joint medical offices produce lower vaccination coverage than group and individual medical offices.

The length of the conversation between parent and physician clarifying the pros and cons of vaccination (measured in minutes) results in a u-shaped functional form. If the pre-vaccination talk is short, the probability of the parents approving immunization is high. If the conversation between physician and parents takes longer, the probability of parents immunizing their children declines; the minimum acceptance of MMR is at about 18 min. If the duration of the conversation is much longer, parental willingness to immunize their children increases again.

Table 1 Results of the parents' survey, logistic regression, weighted, dependent variable: vaccination of their children, 1 = immunization against measles, mumps and rubella (MMR); 0 = no immunization against MMR; Munich vaccination study 2001

	Coef. (z value)
Age	−0.08 (−2.7)**
Low education[a]	1.31 (2.7)**
Belief in use of scientific medicine[b]	1.56 (6.3)***
Organic food is important	−0.68 (−2.5)*
Danger of the illness	1.73 (6.6)***
Distance to the physician's office (min)	−0.03 (−2.4)*
Constant	4.09 (3.3**)
N	426
Pseudo R^2	0.25
Hosmer–Lemeshow sig.	0.53
Overall	75%

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

[a] Ref.: university entrance diploma

[b] Ref.: believe in use of homeopathy or/and naturopathy

Table 2 Results of the physician survey, OLS regression, weighted, dependent variable: physician–individual–vaccination rate against MMR, Munich Vaccination Study 2001

	Coef. (t value)
Age (10 years)	0.07 (2.0)*
Joint medical office[a]	−0.26 (−3.1)**
Duration of consulting	−0.04 (−2.7)**
Duration of consulting (squared, 10 min)	0.01 (3.1)**
Vaccination literature	0.03 (1.8)
Administration of patients using PCs	0.17 (3.0)**
Degree in homeopathy	−0.05 (−0.7)
Constant	0.52 (2.1)*
N	100
R^2	0.38

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

[a] Ref.: group and individual medical office

The availability of literature (e.g., posters, flyers, brochures) at the doctor's office has no impact on whether or not a child is vaccinated. Medical practices using patient management software achieve higher rates of immunization. The effect of further training in homeopathy is not significant. Doctors practicing scientific medicine and those trained in homeopathy produce the same vaccination coverage.

The following results are derived from multilevel analysis. The random intercept-only model is highly significant (t value: 5.54, not shown in Table 3), indicating variation at the physician level; so, multilevel analysis is appropriate. MDM 1 shows parent effects after controlling for the influence of physicians.

The three major effects relating to parents (see Table 1) remain constant in MDM 1. The probability of immunization declines with parents' age and parental beliefs in the use of homeopathy. The belief that illness is hazardous has a positive effect. The effects of education (t value 1.95) and preference for organic food lose their significance in the multilevel analysis (MDM 1 and 2). MDM 2 shows parental and physician effects. Even here, parental effects on the MMR decision remain the same. The u-shaped physician-level effect of consultation duration vanishes while the other physician effects are slightly changed. MDM 3 introduces the cross-level effect of parental and physicians' age to measure homophily. This effect is significant and negatively signed, which means that the age of physicians reduces the effect of parental age. Young parents are less likely to immunize if they interact with older physicians, but older parents are more likely to have their

Table 3 Multilevel analysis, logistic regression, population-average models (fixed effects, parent weight, physician weight, robust standard errors, dependent variable: 1 = immunization against MMR, 0 = no immunization against MMR), Munich Vaccination Study 2001

	MDM 1 Coef. (*t* value)	MDM 2 Coef. (*t* value)	MDM 3 Coef. (*t* value)
Parents' survey data (level 1)			
Age	−0.09 (−2.58)*	−0.09 (−2.11)*	−0.14 (−2.75)**
Low education[a]	1.24 (1.95)	1.33 (1.63)	1.49 (2.15)*
Belief in scientific medicine[b]	1.34 (3.74)***	1.34 (3.27)**	1.36 (3.20)**
Organic food is important	−0.63 (−1.59)	−0.79 (−1.62)	−0.77 (−1.56)
Danger of the illness	1.18 (3.37)**	1.28 (2.97)**	1.23 (2.85)**
Distance to the physician (min)	−0.02 (−1.88)	−0.02 (−1.60)	−0.02 (−1.61)
Physicians survey data (level 2)			
Age (10 years)		0.99 (3.82)***	1.22 (4.99)***
Vaccination literature		0.05 (0.59)	0.04 (0.52)
Administration of patients using PCs		−0.51 (−1.17)	−0.43 (−0.97)
Duration of consulting		−0.12 (−1.13)	−0.14 (−1.41)
Duration of consulting (sq., 10 min)		0.03 (1.24)	0.04 (1.52)
Degree in homeopathy		−0.57 (−1.62)	−0.62 (−1.60)
Joint medical office[c]		−1.06 (−3.05)**	−1.11 (−2.94)**
Cross-level effects			
Age (physician) × age (parents)			−0.02 (−2.66)**
Constant	1.37 (7.28)***	1.59 (7.64)***	1.61 (7.26)***
N physicians	94	94	94
N parents	348	348	348

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

[a] Ref.: university entrance diploma

[b] Ref.: believe in use of homeopathy or/and naturopathy

[c] Ref.: group and individual medical office

children immunized if the doctor is their age. When measured in terms of age, homophily favors vaccination. The introduction of the cross-level effect strengthened the effect of parents' education. Low levels of education are positively associated with high vaccination coverage.

Discussion

Young parents vaccinate their children more often than do older ones. One possible explanation is young parents' uncertainty over the appropriateness of their health-care decisions. This may lead them to take a more cautious and comprehensive approach to their children's treatment. Older parents have more established routines for dealing with illness and may take aspects of their children's health for granted. This may lead to less comprehensive treatment. Far more crucial than the effect of age is one's beliefs about alternative medicine: specifically, beliefs about homeopathy and naturopathy. Parental beliefs in these approaches are major obstacles to comprehensive vaccination coverage. This result is not new. But the analysis shows that preferences over the use of homeopathy exist prior to physician selection. This finding is important and has been overlooked by the literature until now. A strict analysis of physician data ignores the fact that patients do not select doctors at random, but based on their attitudes toward homeopathy. Homeopathic physicians do not, therefore, lead to lower vaccination rates.

The study yields other interesting results about physician effects. Joint medical offices produce lower vaccination rates than group and individual medical offices. This may reflect a collective action problem. Management of a joint pool of patients diffuses responsibility for monitoring vaccinations, which may decrease vaccination rates. Another interesting result is that coverage is significantly higher for practices using patient management software. These software solutions appear to make it easier to remind parents to vaccinate their children, though this benefit needs to be weighed against the costs of these solutions (Lieu et al. 1997).

Multilevel analysis is an appropriate way of modeling the complex and interrelated determinants of vaccination rates. Unfortunately, this approach was limited to relatively small regions as a nationwide sample would have made it impossible to assign parents to their physicians. Thus, regional effects remain unstudied.

One possible limit to this study is the fact that it is not guaranteed that children are vaccinated by physicians named by parents, because parents often change their children's doctors between childbirth and school entry health checkup. But, the effects are significant in spite of this limitation. Maybe even stronger effects would result if the physicians named by parents vaccinated the children for certain.

A more serious limitation is the missing data resulting from missing vaccination logs. A missing value study might be useful, since logs do not likely go missing at random.

Future research might also consider why some parents opt for an "individual vaccination schedule" in which they elect only to vaccinate their children against one or two of the possible diseases rather than the standard approach of vaccinating against all three. Finally, researchers could also examine the vaccination patterns of non-Germans, a group that was not well represented in this study. The theoretical discussion identified homophily as a crucial factor for parent–physician communication. Even after controlling for selection effects, similarity between parents and physicians improves the acceptance of vaccinations, e.g., older physicians in combination with older parents produce higher vaccination coverage. But similitude only works for age. Education affects parents' ability to process complex information and manage long-term investments in individual health production, but it also makes parents less submissive. Mothers with lower levels of education are more likely to obey the doctor, whereas mothers with higher education levels try to fully investigate the benefits of immunization.

High levels of vaccination coverage are attainable if the parent–physician engagement with MMR is managed properly. Homeopathic physicians do not hinder vaccination coverage, so efforts to influence or manipulate these physicians are unnecessary. It is the parental attitude toward homeopathy that matters. The parent–physician communication should especially take into consideration the duration of pre-vaccination discussion and the educational level of parents. Highly educated parents discuss the benefits of immunization at length. Physicians should prepare themselves to respond to these parents' questions. Further training would help physicians develop strategies for convincing parents who are not easily persuaded. They could, for example, stress vaccination coverage for herd immunity (Skea et al. 2008). Communicative strategies should focus on women, since they are the ones most responsible for immunization decisions. With the exception of education levels, homogeneity of parents and physicians increases the likelihood of vaccination. This is particularly true of parents and physicians of similar ages.

Acknowledgments The author is grateful to Monika Jungbauer-Gans and the German Research Foundation (DFG) for supporting the project. I thank Ralf Karhausen-Beermann and the Munich Ministry of Health and Environment for access to the school entry health checkup data, and Catherine Bennewitz, Kyle Hanniman and the two anonymous reviewers for helpful suggestions to improve the manuscript.

Conflict of interest The author declares that he has no competing interests.

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