Aus dem Robert Koch-Institut

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DISSERTATION

Barriers and drivers to vaccination among healthcare workers in Germany

zur Erlangung des akademischen Grades

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1 Zusammenfassung

1.1 Abstract (Deutsch)

Eine geringe Impfbereitschaft ist eine relevante Bedrohung für die weltweite Gesundheit. Die Gründe nicht zu impfen sind divers. Beschäftigte im Gesundheitswesen spielen eine zentrale Rolle als impfende Akteure und als Empfänger von Impfungen. Diese Dissertation hatte zum Ziel (i) hemmende und fördernde Faktoren für das Impfen bei Gesundheitspersonal in Deutschland zu untersuchen und (ii) Impflücken bei Gesundheitspersonal zu identifizieren. Weiterhin sollte untersucht werden, (iii) ob das Gesundheitspersonal Impfpflichten als Mittel zur Steigerung von Impfquoten positiv gegenübersteht.

Es wurden Befragungsdaten von Hausärzt*innen, Krankenhauspersonal und Ärzt*innen der Primärversorgung erhoben. Die Impfquoten für verschiedene Impfungen und das Impfempfehlungsverhalten bei Gesundheitspersonal wurden erfragt. Weiterhin wurden psychologische Determinanten des Impfverhaltens und weitere Barrieren für das Impfen erfasst. In allen Studien wurden die Zusammenhänge zwischen den Prädiktoren und den Zielvariablen in linearen und logistischen Regressionsanalysen untersucht.

Die Befragungsdaten zeigen, dass es relevante Impflücken bei Hausärzt*innen und Krankenhauspersonal gibt. Diese variieren je nach Impfung (Masern, Influenza, Hepatitis B), Umfeld (Krankenhaus, Arztpraxis) und Zielgruppe (Pflege, Ärzteschaft). Der Großteil der Hausärzt*innen empfiehlt den Patient*innen Impfungen aktiv.

Von den psychologischen Determinanten des Impfverhaltens war das Vertrauen in die Impfung (Confidence) bei Hausärzt*innen mit dem eigenen Impfstatus und dem Empfehlungsverhalten assoziiert. Gemeinsinn (Collective Responsibility), praktische Barrieren (Constraints) und eine niedrige Risikowahrnehmung (Complacency) waren mit dem eigenen Impfstatus assoziiert. Bei Krankenhauspersonal waren praktische Barrieren und fehlendes Vertrauen die Hauptgründe, sich nicht gegen Influenza impfen zu lassen.

86% der Ärzt*innen befürworteten die neu eingeführte Masernimpfpflicht. Die Einstellung zur Impfpflicht war mit den erwarteten Konsequenzen assoziiert, bspw. der Überzeugung, die Impfquote würde dadurch steigen. Je größer Confidence und Collective Responsibility der Ärzt*innen, je höher die Risikowahrnehmung (niedrige Complacency) und je geringer das Bedürfnis nach Informationen und Abwägung (Calculation), umso mehr befürworteten die Befragten Impfpflichten.

Die Ergebnisse haben strategische Implikationen. In Krankenhäusern sollte der Zugang zu Impfungen erleichtert werden. Ärzt*innen befürworten die neue Masernimpfpflicht überwiegend. Dennoch finden sich einige Bedenken, bspw. ob eine solche Impfpflicht ihr Ziel erreicht. Die Einführung der Masernimpfpflicht sollte in Bezug auf das Erreichen der Ziele evaluiert werden. Die psychologischen Determinanten sind sowohl für das Impfverhalten als auch die Einstellung zur Impfpflicht relevant. Daher können Interventionen, die Confidence, Collective Responsibility und Complacency adressieren, sowohl eigenes Impfverhalten motivieren als auch das Wohlwollen gegenüber einer neuen Impfpflicht erhöhen.

1.2 Abstract (English)

Vaccine hesitancy is a major threat to global public health. Reasons not to vaccinate are multifaceted. Healthcare workers (HCWs) are key figures in the vaccination system – both as vaccine providers and vaccine recipients. This dissertation project aimed to (i) investigate barriers and drivers to vaccination among HCWs in Germany and (ii) identify vaccination gaps among HCWs. It further aimed to (iii) investigate whether HCWs favor vaccine mandates as an intervention to increase vaccine uptake.

Survey data was collected from family physicians (FPs), hospital staff and primary care physicians. HCWs' vaccination coverage for various vaccines and recommendation behavior were assessed. Further, we assessed psychological determinants of vaccination and additional barriers to vaccination. Lastly, we assessed psychological determinants of physician attitudes towards vaccine mandates. In all studies, associations between outcomes and determinants were examined using linear and logistic regression analysis.

The surveys revealed that there are relevant vaccination gaps among FPs and hospital staff. These vary by vaccine (measles, influenza, hepatitis B), by setting (hospital, private practice) and by target group (nurses, physicians). The majority of FPs claimed to actively recommend vaccines to patients.

Of the psychological determinants, vaccine confidence was associated with FPs' own vaccination status and recommendation behavior. Collective responsibility, constraints and complacency were associated with own vaccination status. Among hospitals staff, constraints and lack of confidence were the main reasons not to get vaccinated against influenza.

Regarding the newly introduced measles vaccine mandate, 86% of physicians expressed being in favor of it. The attitude towards the mandate was associated with its projected consequences, e.g., believing that it will increase vaccination coverage. The higher physicians scored on confidence and collective responsibility and the lower on complacency and calculation, the stronger they were in favor of vaccine mandates.

These findings have several policy implications. In hospital settings access to vaccines should be made more convenient. Private physicians were predominantly in favor of the newly implemented measles vaccine mandate. However, some reservations can be found, e.g., with regards to the effectiveness of such a mandate. The introduction of the mandate should be evaluated with regards to its outcomes. Furthermore, we found that psychological determinants for vaccination behavior and attitude towards vaccine mandates overlap. Hence,

interventions addressing confidence, collective responsibility and complacency will both motivate vaccination behavior and foster a friendly reception of a mandate.

1.3 Introduction

1.3.1 The value of vaccines

Vaccines save millions of lives worldwide every year and prevent disability, sickness and suffering (1). Due to the introduction of vaccines, the burden of several infectious diseases such as poliomyelitis and measles has been drastically reduced (2). Regional elimination (measles) or global eradication (poliomyelitis) of some diseases are in-reach national and international public health goals (3-6). Over the past two decades, with the availability of new vaccines and better knowledge of the burden some disease pose to society, vaccines became an integral part of prevention not only for children but also for adolescents, pregnant women and older adults (4). Vaccines can have a positive impact on individual health and health systems in numerous ways: They do not only prevent infections, but can prevent the onset of cancer (HPV and hepatitis B vaccines) (7). They can reduce the use of antibiotics and hence contribute to the fight against anti-microbial resistance (e.g., pneumococcal vaccines, haemophilus influenzae B vaccine) (8). They reduce the number of sick-days (9) and hospital admissions which alleviates pressure on the healthcare system. Thus, during the COVID-19 pandemic for example, influenza and pneumococcal vaccination were strongly recommended to older adults (10) in order to prevent influenza- and pneumococcal-related hospital admissions (11).

Why is it then that many people are not fully protected from vaccine-preventable diseases? What if safe and effective vaccines are available, but people decide not to take them? In the COVID-19 pandemic for example – while hospitals were overcrowded and deaths steadily rising – a significant fraction of the German population was hesitant to get the COVID-19 vaccine (12). Strikingly, even healthcare workers (HCWs) were hesitant to get vaccinated (13). This example underlines that the success of vaccines depends greatly on communities that recognize its value and demand vaccination. The World Health Organization (WHO) has recognized the problem and subsequently singled out vaccine hesitancy as one of the top ten global public health threats in 2019 (14). The European Council has requested for member states to act against vaccine hesitancy (15). Understanding vaccine hesitancy and finding proper ways to address it is an important public health goal. This implies investigating the specific determinants of vaccination behavior in order to anticipate which interventions might work and which will not.

1.3.2 The phenomenon vaccine hesitancy

Vaccine hesitancy has been defined as not getting vaccinated despite having access to vaccination (16). It is understood as a continuum between full acceptance and full rejection, where some individuals might be hesitant regarding all, some or no vaccines (Figure 1). Thus, while some people might be unquestioning acceptors of vaccines, others are cautious acceptors or they vaccinate late or selectively and even others are outright refusers (17). Vaccine hesitancy is not restricted to one region or subset population. Temporary decline in vaccination uptake occurred in contexts as different as the pH1N1 pandemic among pregnant women in the Americas, the measles vaccine in Europe, the HPV vaccine in Japan and India and the polio vaccine in Nigeria and Pakistan (18).

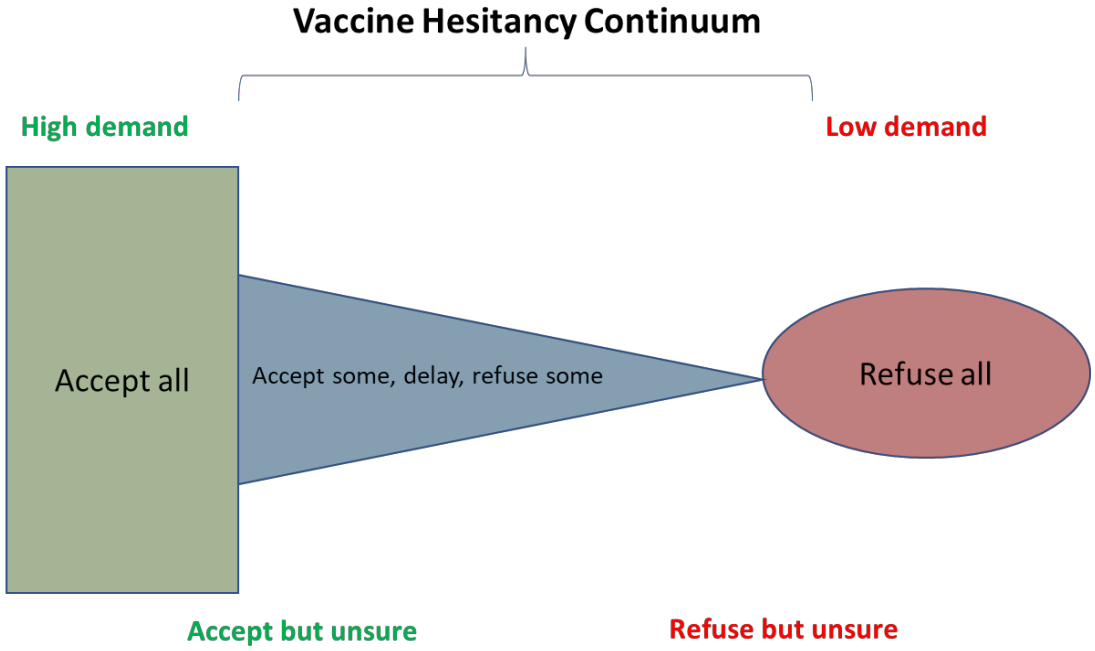

Figure 1: Vaccine hesitancy is a continuum between full acceptance and full rejection. Note: *adapted from (16).*

Vaccine hesitancy is a catchall category to describe a phenomenon – non-vaccination – which has distinctly different antecedents (19). E.g., while some people might simply not know where and how to get a vaccine, others might hesitate to get a vaccine due to safety concerns. In recent years, there were considerable advances in the methodologies and tools that can be applied to measure vaccine hesitancy:

The WHO initiated the SAGE Working Group on Vaccine Hesitancy in 2011 (20), which then identified three core elements of vaccine hesitancy, the 3C, which stand for complacency, confidence and convenience (or constraints) (16). Betsch et al. extended this model and developed a new measure that can be regarded as more comprehensive: the 5C

psychological determinants of vaccination (21). These 5C capture – from an individual's perspective – predictors of an individual's vaccination behavior:

- Confidence: "is defined as trust in (i) the effectiveness and safety of vaccines, (ii) the system that delivers them, including the reliability and competence of the health services and health professionals, and (iii) the motivations of policy-makers who decide on the need of vaccines" (16).
- Complacency: "exists where perceived risks of vaccine-preventable diseases are low and vaccination is not deemed a necessary preventive action" (16).
- Constraints/Convenience: are an issue when "physical availability, affordability and willingness-to-pay, geographical accessibility, ability to understand (language and health literacy) and appeal of immunization service affect uptake" (16).
- Calculation: "refers to individuals' engagement in extensive information searching. We assume that individuals high in calculation evaluate risks of infections and vaccination to derive a good decision" (21). "High involvement and calculating can also lead to an abundance of contradictory information" (22) – which can make individuals vaccine hesitant.
- Collective responsibility: is defined "as the willingness to protect others by one's own vaccination by means of herd immunity. The flip-side is the willingness to free-ride when enough others are vaccinated" (21).

Vaccine hesitancy is moreover recognized to be vaccine specific and context-specific (16). That is, the reasons not to vaccinate, e.g., against influenza might differ from the reasons not to vaccinate against, e.g., measles. Reasons for non-vaccination might also be different for adults or for children, e.g., while in children vaccines are provided during regular health check-ups, such regular reminders are not in place for adolescents and adults (23). Hesitancy might also differ locally, e.g., health beliefs in anthroposophical communities might be a barrier to vaccination (24).

These considerations and other behavioral insights research have led the WHO to recommend a structured process to obtain insights into the specific local barriers and drivers to vaccination and design tailored interventions for increased uptake based on these findings (Tailoring Immunization Programmes (TIP) approach) (25). The TIP approach foresees identifying a target group that deserves, e.g., due to lower vaccination coverage or high susceptibility to vaccine preventable diseases, further investigation. A research project should then investigate the specific barriers and drivers to vaccination in this target group in a comprehensive manner. TIP's focus is to enable a country or a region to reach a target

specified in a respective health program, e.g., reaching high measles vaccination coverage so that measles elimination can be achieved. Thus, TIP aims to generate context-specific evidence on barriers and drivers to vaccination that can be translated into interventions to increase vaccine uptake.

In this dissertation the above-mentioned methodologies – the 3C and 5C psychological antecedents of vaccination and the TIP approach – were applied as a framework to identify barriers and drivers underlying vaccination behaviors.

1.3.3 Healthcare workers as key figures in the vaccination program

This dissertation project investigated vaccine hesitancy among HCWs. HCWs have increasingly gained interest in the vaccine hesitancy research field (26, 27). HCWs are important in two ways: as vaccine providers and as vaccine recipients.

First, HCWs as vaccine providers are multipliers of vaccination. Physicians – primarily pediatricians and family physicians (FPs) – administer the majority of vaccines in Germany. They have an overview over their patients' medical conditions and subsequent indication for vaccination. They are the ones who recommend a vaccine and remind a patient of it. Building on their vaccine knowledge they inform patients about the risks and benefits of vaccines, with their communicative skills they answer to patient worries and anxieties around vaccines. HCWs are the most trusted source when it comes to vaccine decision-making: 9 in 10 individuals living in Germany consult their doctor when they are looking for information on vaccination and 8 in 10 trust their doctor most for information on vaccination (28, 29). HCWs recommendation guides patient vaccination behavior (30-32). Secondly, HCWs are important vaccine recipients – they tend to be at higher risk of exposure to infectious diseases and are more likely to transmit infectious diseases to vulnerable people they have contact with. In Germany, the Standing Committee on Vaccination (STIKO) recommends healthcare workers to be vaccinated against several diseases, including measles and seasonal influenza (33).

Despite this critical role, only little is known about the motivations and hesitancy related to vaccination among HCWs in Germany. Although HCWs are generally regarded to be pro-vaccine, there is increasing awareness that they can be vaccine hesitant too (34). In fact, they might not differ much from the general population in that they also at times have doubts regarding e.g., vaccine safety or vaccine necessity (27, 35, 36). In their role as vaccine providers HCWs might face additional challenges such as high workload, inadequate information and difficulty to answer patient questions (37). Hence the **first research goal** of

this thesis was to **investigate barriers and drivers to vaccination among HCWs in different settings.**

1.3.4 Vaccination gaps in Germany

In Germany, vaccination coverage for routine childhood immunization is generally high, but significant vaccination gaps exist among adolescents and adults (38). Also, there is regional variation of vaccination coverage, and vaccination is often times not timely and incomplete (39). In this dissertation project we focused primarily on the measles and influenza vaccine.

The measles vaccine is recommended in Germany for everyone born after 1970 (40). Vaccination coverage for the measles vaccine in children is high (97% first dose school children) and has been increasing over the last years (Figure 2) (39). Still, measles vaccination is often times not timely and incomplete, and there is local variation of vaccination coverage (39). Further on vaccination gaps exist among adults: A study from 2013 found coverage with one dose of measles vaccine to be 80% for young adults aged 18–29 years in Germany and 47% for those 30–39 years of age (41). So far, no country level data on measles vaccination coverage among HCWs existed in Germany. From a public health perspective, measles vaccination coverage has to be very high (around 95%) to achieve herd protection and eventually eliminate measles, as measles are highly infectious (basic reproduction number: 15-18) (42, 43). Regional clusters of under-immunization can undermine herd protection and fuel regional outbreaks.

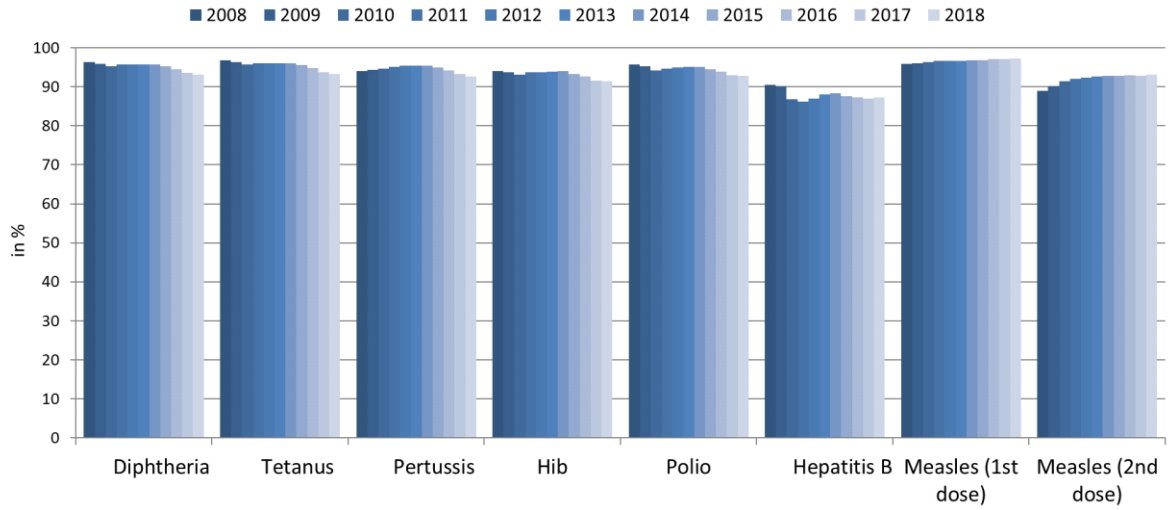

Figure 2: Vaccination coverage among children at school-entry in Germany 2008-2018. Note: *adapted from (39).*

Influenza vaccination is recommended to HCWs, older adults, pregnant women and people with chronic underlying medical conditions (40). Influenza vaccination programs aim to reduce the health burden of influenza and to protect vulnerable populations (44). Therefore, the Council of the European Union calls for an influenza vaccination coverage of 75% for older adults and other risk groups (45). The influenza vaccination coverage in Germany – at least in older adults – saw a steady decrease over the last years (Figure 3) (38). In 2016/17 only 35% of adults aged 60+ years were vaccinated against influenza; vaccination coverage was even lower for pregnant women and for individuals with chronic conditions. Recently, however, after an especially severe influenza season in 2017/18 with 25,100 deaths (46), vaccination coverage increased. Among HCWs, individual studies found influenza vaccination coverage to be low, with local variation (47-49). However, data is scarce and not systematic. So far, no country level data on influenza vaccination coverage specifically among HCWs existed in Germany.

Hence, the **second research goal** was to **assess HCWs' own vaccination status and recommendation behavior, i.e., identify vaccination gaps, in different settings.**

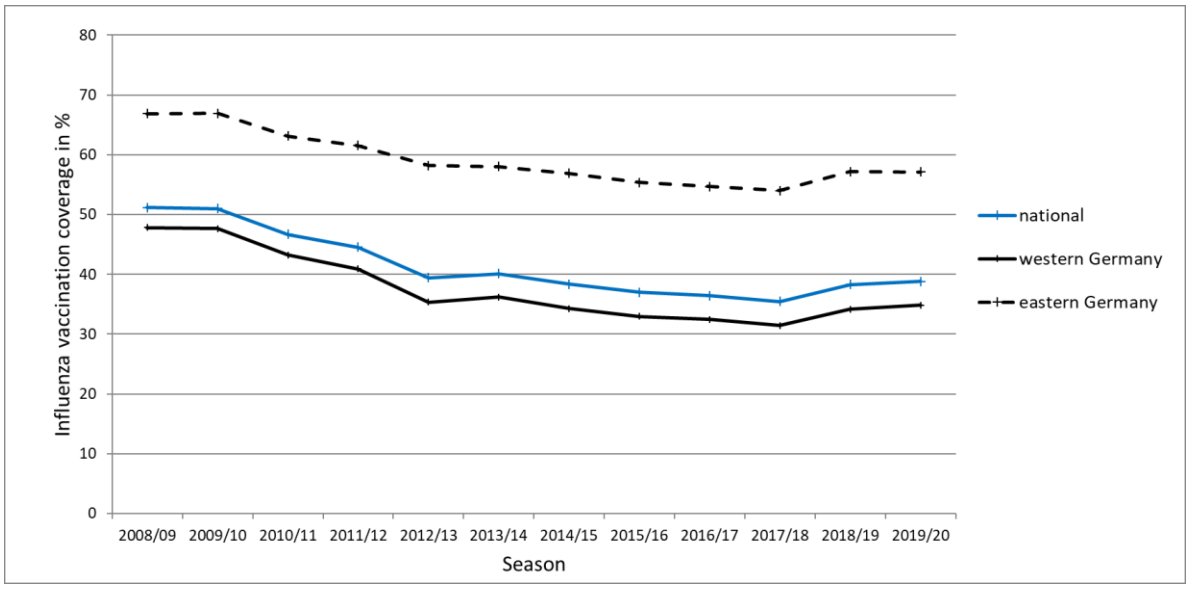

Figure 3: Influenza vaccination coverage among seniors over 60 years of age, 2008/9- 2019/20 (in %), national, in western Germany, in eastern Germany. Note: *adapted from (38).*

1.3.5 Interventions to increase vaccine uptake

As vaccine hesitancy is a multifaceted phenomenon, interventions addressing it are multifaceted as well. Depending on the problem analysis – why is it that people do not get vaccinated – a different intervention may fit. E.g., lack of confidence may be addressed by debunking myths about vaccines and strengthening trust in public health authorities, while

difficult access to vaccination (constraints), might need a structural intervention, e.g., introducing reminder systems (22). Trying to compensate for a lack of confidence with structural interventions is unlikely to work, as individuals with a lack of confidence care about their vaccination decision and will rather look for ways to opt-out than get vaccinated (22). The TIP approach gives guidance as to which interventions should answer which problem (25). In general, interventions that facilitate vaccination directly, e.g., reminder systems, prompts, incentives, and sanctions, have shown to be much more effective in increasing vaccine uptake, than educational campaigns alone (though they may generate support for vaccination policies and programs) (50).

In Germany there was an ongoing debate about how to address measles vaccination gaps in order to avoid further measles outbreaks. While vaccination coverage was generally high it was not high enough to eliminate measles and national efforts did not change that (5). In the context of the 2018 European Council recommendation to take action against vaccine hesitancy (15), the WHO listing vaccine hesitancy as one of the ten threats to global health in 2019 (14), large outbreaks of measles in Germany (Figure 4) and the European region (51), and new mandates in Italy (52) and France (53), discussion evolved regarding a mandatory measles vaccination policy in Germany.

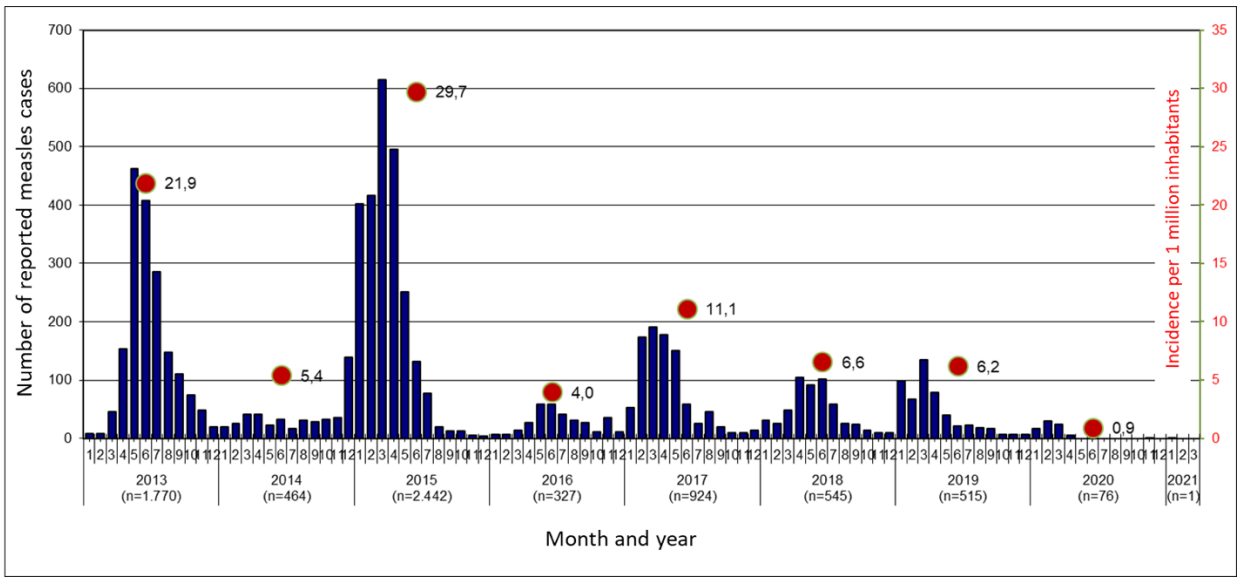

Figure 4: Number of reported measles cases per months 2013-2021 in Germany (54).

A mandate was considered to be one option among others to increase vaccine uptake and as such both the governing parties and medical societies as well as other stakeholders

supported it (55-57). Some stakeholders, however, expressed concerns regarding the legal, sociological and ethical dimensions of such a mandate, e.g., the German Ethics Council (58).

Moreover, potential psychological consequences were discussed, such as detrimental effects on the willingness to vaccinate against diseases where vaccination remained voluntary (59-61). The result of the controversy was a law that encompassed – beyond a mandate – different aspects to strengthen the immunization system in Germany. The so-called Measles Protection Act came into effect in March 2020 and included a new mandatory policy on measles vaccination, requiring proof of measles immunization for all children and staff in childcare and schools, as well as HCWs (62). If individuals are not able to provide this proof, a variety of sanctions can be implemented: access to pre-school childcare can be rejected, at school penalties up to EUR 2,500 can be collected, new employment can be rejected, and employees can be deployed elsewhere. Exemptions exist for individuals with proof of naturally-acquired immunity or with medical contraindications, e.g., allergy to vaccine components.

A mandate seeks to modify behavior by sanctioning non-behavior. Thus, non-behavior becomes less favorable as consequences are harsh. As such it does not aim to change thoughts and feelings about vaccines. It might however set new social norms or foster pre-existing norms, thus interacting with attitudes towards vaccines (22). Mandates can be effective if implemented with care and in consideration of context (59). HCWs play a special role in this: as vaccine providers they are experts on vaccination services and can project consequences of such a mandate. In addition, the successful implementation of the mandate depends upon them. HCWs vaccinate the ones considered under the mandate, they have to ensure that their staff is vaccinated and they themselves have to be vaccinated, too. Understanding if and why physicians consider a mandate an appropriate intervention to increase vaccine uptake will help further deepening our understanding as to where the barriers and drivers to vaccination lie and how best to address them. Hence, the **third research goal** was to **assess in how far HCWs regard vaccine mandates as an appropriate intervention to increase vaccine uptake in Germany.**

1.3.6 Aims of the research project

Summing up, the research project of this thesis encompassed three research goals. First, it aimed to investigate barriers and drivers to vaccination among HCWs in different settings. Secondly, it aimed to assess in how far HCWs are vaccinated and do recommend vaccines to their patients – i.e., the current state of vaccination behavior – in different settings. And third,

it aimed to assess in how far HCWs, our key vaccine providers, regard vaccine mandates as an appropriate intervention to increase vaccine uptake in Germany.

The dissertation encompassed the following three studies, the first and second goal were addressed in study 1 and 2 and the third goal in study 3:

Study 1: Assessing barriers and drivers to adult vaccination among FPs in order to gain insights for tailoring the immunization program in Germany.

➔ To be found in publication 1 (Neufeind J, Betsch C, Habersaat KB, Eckardt M, Schmid P, Wichmann O. Barriers and drivers to adult vaccination among family physicians – Insights for tailoring the immunization program in Germany. Vaccine. 2020;38(27):4252-62. (63))

Study 2: Establishing a monitoring system for influenza vaccination coverage and acceptance among German hospital staff.

➔ To be found in publication 2 (Neufeind J, Wenchel R, Boedeker B, Wicker S, Wichmann O. Monitoring influenza vaccination coverage and acceptance among health-care workers in German hospitals - results from three seasons. Human Vaccines & Immunotherapeutics. 2020;17(3):664-72. (64))

Study 3: Assessing determinants of physician attitudes towards the new selective measles vaccine mandate in Germany.

➔ To be found in publication 3 (Neufeind J, Betsch C, Zylka-Menhorn V, Wichmann O. Determinants of physician attitudes towards the new selective measles vaccine mandate in Germany. BMC Public Health. 2021;21(1):566. (65))

1.4 Methods

1.4.1 Study design

All studies consisted of survey data (telephone, online and paper-and-pencil) and had different groups of HCWs (private physicians and hospital staff) as the study population (Table 1). Samples were random (study 1) or convenience (study 2 and 3). All studies applied incentives.

Table 1: Overview of the studies included in this dissertation.

	Type	Data collection	Reason for sample selection	Research sample	Sample size, N=
study 1	Computer assisted telephone interviews (CATI)	2017/18	Primary providers of adult vaccination	Internists or general practitioners in primary care	700
study 2	Multi-centre study, online survey	2017	Important vaccination target groups	All hospital staff	52 hospitals, 5,808 participants
	Multi-centre study, online survey	2018	Important vaccination target groups	All hospital staff	125 hospitals, 17,891 participants
	Multi-centre study, online survey	2019	Important vaccination target groups	All hospital staff	172 hospitals, 27,163 participants
study 3	Mixed-mode online and paper-and-pencil questionnaire	2020	Primary providers of vaccination	Pediatricians, general practitioners, gynecologists, internists in primary care	2,229

Study 1 computer-assisted telephone interviews (CATI)

A national random sample was drawn from a public telephone register of FPs. FPs included in the sample were identified as internists or general practitioners responsible for primary care. The regional distribution of the interviews was controlled by drawing the addresses in proportion to the number of inhabitants per federal state. Trained professional interviewers contacted the doctor's practice via telephone during main working hours and on workdays only. The interview took place immediately or at a later appointment and was conducted as a computer-assisted telephone interview. Data was obtained in December 2017 and January 2018.

Study 2 multi-centre, online survey

In a first step, hospitals were contacted and asked for their support and participation in the study. The German Hospital Federation sent a letter about the online monitoring system on influenza vaccination coverage in German hospitals (OKaPII) to all its members, while private hospital operators were contacted individually. As an incentive, participating hospitals were provided with an annual report that summarized clinic-specific results and aggregated results from the other participating hospitals as a benchmark. For the data collection, the web-based Voxco Survey Software was used (Version 5.5.1 Group Voxco, Montreal, Canada). In each participating clinic a contact person was identified who served as a multiplier. The multipliers forwarded the link to the online survey to all hospital staff via employees' professional e-mail addresses. After an initial pilot phase in 2016, country-wide roll out took

place in 2017 in autumn, then data collection took place after the end of each influenza season in spring 2018 and 2019.

Study 3 mixed-mode online and paper-and-pencil questionnaire

The study was conducted in a mixed-mode design as an online and paper-and-pencil questionnaire. The survey was sent out as a paper-and-pencil survey to 90,000 private physicians as a supplement to Deutsches Ärzteblatt, the major medical journal in Germany that is provided free of cost to all physicians. The distribution of the questionnaire was limited primarily to general practitioners, internists, pediatricians, and gynecologists – the primary vaccine providers in Germany. On the survey, a QR code and link to the online survey was provided for convenience. In addition, a link to the online survey was sent via e-mail newsletter to subscribers of Deutsches Ärzteblatt and, for registered users only, posted on the respective website of the journal. Data was obtained from January to March, 2020.

1.4.2 Questionnaires

The respective questionnaires were designed on the basis of literature research and in consultation with vaccination experts. Where available we relied on validated survey questions. For study 1, we additionally conducted five qualitative interviews with experts in the field to identify topics that might constitute barriers or enablers to vaccination for FPs.

In study 1, the primary study outcome was FPs' own vaccination status (influenza, hepatitis B, pertussis) and their recommendation behavior (measles, influenza) to their patients. We assessed the 5C psychological determinants of vaccination. Further on we included sociodemographic characteristics, i.e., age, gender, city size, region and membership in a medical society as potential determinants. To explore other possible barriers and drivers to vaccination we assessed FPs' institutional trust, promotion mechanisms (e.g., use of reminder systems), contextual barriers (e.g., vaccine shortages), sources of information (e.g., official sources vs. other sources), and vaccination-related beliefs.

In study 2, the primary study outcome was hospital staff's own influenza vaccination status. We further included the vaccination status for measles and hepatitis B vaccine. We assessed reasons for and against the influenza vaccine. Reasons against the influenza vaccine were designed on the basis of the 3C-model. We further included sociodemographic characteristics and some hospital characteristics as potential determinants of influenza vaccine uptake.

In study 3, the primary study outcome was private physicians' attitude towards vaccine mandates. In addition, we developed items to assess physicians' projected consequences of the Measles Protection Act in their practice. We assessed the 5C psychological determinants as potential determinants of physician attitudes towards mandates. To explore other possible determinants of physician attitude towards mandates we included 'communication self-efficacy', and their patients' level of vaccine hesitancy ('patient clientele'). We further assessed physicians' vaccine knowledge and their attitudes towards other interventions to increase vaccine uptake.

1.4.3 Statistical analysis

Analysis was conducted in R (66). The main analyses in all studies were logistic or linear multivariate regression models in which the determinants of respective behaviors (study 1 and 2) and attitudes (study 3) were assessed (Table 2). In study 1, we additionally implemented a nonparametric conditional inference tree as an alternative method to assess determinants of vaccination behavior, a method that can control for potential higher-order interactions among variables. In study 3, we included a mediation analysis to test for a mediation observed in the regression model. In detail these were the main analyses:

For study 1, we performed blockwise logistic regression to identify factors associated with own vaccination behavior (i.e., being vaccinated according to STIKO as described above) and active recommendation (of influenza or measles vaccine) to patients. Each starting model contained sociodemographic characteristics, in a second step membership in a medical society and in a third step the 5C psychological determinants were included. We optimized all models with stepwise forward and backward selection by using the Akaike Information Criteria (AIC). In addition, for influenza vaccine only, we implemented a nonparametric conditional inference tree for own vaccine uptake and active recommendation of vaccines. Tree models allow for the detection of the most influential variables (67). ntree = 5,000 random trees were grown to verify the results (68-70). We included the same set of covariates we had included in the logistic regression analysis.

For study 2, we performed multivariate logistic regression analysis to identify factors associated with influenza vaccination status. We analyzed the different data sets separately for the 2017, 2018 and 2019 data. This approach allowed us to detect differences from season to season and to control for the fraction of hospital staff that had participated repeatedly. The outcome variable was whether participants were vaccinated against influenza in the respective season (2016/17, 2017/18, 2018/19) or not. We included sociodemographic characteristics

(age, gender, work area, region), access to the vaccine (offered at workplace or not), hospital size, vaccination status for other vaccines (protection against measles in 2018 data and hepatitis B vaccination status in 2019) and individual risk factors (chronic disease, patient contact) as independent variables. All variables were entered at once into the model.

For study 3, we performed blockwise multiple linear regressions to identify correlates of the attitude towards vaccine mandates. Model one contained sociodemographic characteristics, i.e., work experience, gender, region, city size, and occupational group. In the second step, 'communication self-efficacy' and 'patient clientele' were added. The 5C psychological determinants of vaccination were added in a third and the expected consequence ('more children vaccinated') in the final step. Next, we tested for mediation of these relationships. The model included occupational group (pediatrician vs. other physician sub-groups) as the predictor variable, expected consequences of the mandate ('more children vaccinated') as the mediator variable, and attitude towards the mandate as the outcome variable.

Table 2: Main outcomes and analyses conducted by study as part of the dissertation project.

	Main Analysis	**Outcome**	**Predictor**
study 1	Logistic regression & conditional inference trees	Own vaccination status according to STIKO recommendation (influenza, hepatitis B, pertussis), recommendation behavior (influenza, measles)	5C psychological determinants, sociodemographic characteristics, membership in medical societies
study 2	Logistic regression	Own vaccination status (influenza)	Sociodemographic and hospital characteristics
study 3	Linear regression, & mediation analysis	Attitude towards the vaccine mandate	5C psychological determinants, communication self-efficacy, patient clientele, expected consequences of the mandate ('more children vaccinated'), sociodemographic characteristics

1.4.4 Data protection and ethics

The data protection officer at Robert Koch Institute (RKI) approved study 1. The data protection officer of the RKI and the Federal commissioner for Data Protection and Freedom of Information in Germany approved study 2. The Ethics Commission of the University of Erfurt approved survey study 3. All methods were carried out in accordance with relevant guidelines and regulations.

1.5 Results

1.5.1 Response and study population

For study 1, a representative sample of 700 FPs were interviewed. The response rate was 20.4%. On average, respondents were 56.2 years old (SD = 9.2) and had worked as FPs for 19.9 years (SD = 10.7).

In study 2, a monitoring system was subsequently established. In total, 52 hospitals participated in the survey in 2017, 125 in 2018 and 171 in 2019. Hospitals were located across Germany. The hospitals had on average 201–500 beds. Over the three seasons, the number of participating hospital staff increased from 5,808 in 2017 to 27,163 in 2019. Response rate was around 12% in all seasons. The largest groups of participants in all three seasons worked in normal wards or the hospital administration. Around 70% indicated to have contact to patients on a regular basis.

For study 3, we included 2,229 participants in the analysis (1,140 participated via online survey and 1,089 via paper-and-pencil survey). Among these, 1,178 were general practitioners, 259 gynecologists, 416 internists, and 376 pediatricians. On average, respondents had 19 years of work experience and 54.3% were female.

1.5.2 Main results from study 1: vaccine hesitancy among family physicians

Around 60% of physicians reported to be vaccinated against influenza, pertussis and hepatitis B, with widely differing vaccination rates (influenza: 70%, pertussis: 78%, hepatitis B 97%). The majority claimed to recommend vaccines to patients; less than 1% of FPs stated they would usually advise against one of these vaccines. Own vaccination status was significantly associated with the recommendation of vaccines.

Of the 5C psychological determinants, confidence in the safety of vaccines was associated with own vaccination and recommendation behavior, i.e., physicians who scored higher on confidence were more likely to be vaccinated and to recommend vaccines to their patients. Collective responsibility, constraints and complacency were associated with own vaccination status, i.e., individuals who scored higher on collective responsibility and low on constraints and complacency were more likely to be vaccinated. Reasons not to recommend a vaccine differed for influenza and measles vaccine. Poor vaccine efficacy was the main reason not to recommend the influenza vaccine, constraints were the main reasons not to recommend the measles vaccine.

The regression analysis identified two particularly strong associations with FPs' own vaccination status: membership in a homeopathic society and having an office in western Germany. Physicians having an office in western Germany were less likely to be vaccinated according to STIKO recommendation. However, recommendation behavior and also the 5C psychological determinants did not differ between FPs from eastern and western Germany. Homeopathic FPs were both less likely to be vaccinated themselves and less likely to recommend vaccines to their patients. Also, among homeopathic FPs vaccine confidence was significantly lower and complacency higher.

Other barriers and drivers to adult vaccination were found. Institutional trust was associated with both own vaccination status and recommendation behavior. FPs predominantly trusted STIKO's expertise. There was a perception, however, that the National Immunization Technical Advisory Group (i.e., STIKO) was influenced by other interests (14.8%). Vaccine shortages (52.5%) and cost coverage problems (25.6%) were reported frequently as system-related barriers. Around 40% of participating FPs had implemented an office-based reminder system.

1.5.3 Main results from study 2: vaccine hesitancy among hospital staff

Influenza vaccination coverage among hospital staff in season 2016/17 and 2017/18 was similar (39.5% and 39.3%) while it increased by 12% in 2018/19 (52.3%). Uptake was significantly higher for physicians (76% in 2019) than for nurses (46% in 2019). Of the hospital staff, 87.0% were vaccinated against measles and 6.3% claimed to be protected due to natural infection. Measles vaccination coverage was highest among physicians (91.3%) and their vaccination status was also more often complete with 2 doses (73.5% of physicians claimed to have received two doses of measles vaccine compared to 52.2% of nurses). 97.7% of hospital staff were vaccinated against hepatitis B.

Self-protection was the most common reason for influenza vaccination, followed by the protection of the personal environment (friends and family) and the protection of patients. While physicians mainly identified constraints as reasons for not being vaccinated, i.e., 'I've always wanted to, but for organizational reasons, I've not made it', nurses mainly referred to a lack of vaccine confidence and misinformation, i.e., 'the influenza vaccine can cause influenza'. Both physicians and nurses frequently named a poor risk-benefit ratio as a reason for not being vaccinated.

The likelihood to be vaccinated, for both physician and nurses, increased with age and an immunization service at the workplace. Those vaccinated against measles or hepatitis B

were also more likely to be vaccinated against influenza. Nurses from eastern Germany and with chronic medical conditions were more likely to be vaccinated.

1.5.4 Main results from study 3: physician attitudes towards vaccine mandates

Approximately 86% of physicians were in favor of the measles vaccine mandate for children. The attitude towards mandates was predominantly associated with the projected consequences of the mandate for their own practice. The strongest correlation was found for the following two items: (i) the more physicians expected that the new law would help more children to be vaccinated on time, the more they had a positive attitude towards mandates, and (ii) the more physicians expected the mandate to be a burden for the patient-provider relationship, the more they had a negative attitude towards mandates.

Regarding the 5C model, physicians were more in favor of vaccine mandates when they scored higher on confidence and collective responsibility, and lower on complacency and calculation. They were more in favor of vaccine mandates when they had higher communication self-efficacy and a more vaccine-positive patient clientele. Physicians from eastern Germany and with more years of work experience had a more positive attitude towards mandates. Pediatricians were less in favor of mandates for children (80.0%) than other physician subgroups (87.1%). They were also less convinced that a mandate would result in more children getting vaccinated (59.3%) than other physician subgroups (78.3%). In a mediation analysis we found that the expected consequences (‘more children vaccinated’) completely mediated the effect of occupational group on the attitude towards mandates.

1.6 Discussion

Aim of this dissertation was to investigate barriers and drivers to vaccination among HCWs in Germany, a group which is of utmost importance for the success of vaccination programs. In order to fully appreciate this, it is essential to note that the role of HCWs, especially FPs and pediatricians, is two-fold: On the one hand they receive vaccines, on the other they actively recommend them and vaccinate their patients. The attitudes they hold towards vaccines influence both of these behaviors. Hence, interventions that alter their attitudes will likely affect their own vaccination status as well as their role as multiplicators (37).

The three conducted studies offer a broad overview: They touch upon HCWs both as vaccine recipients and as vaccine providers. They cover vaccine hesitancy among HCWs in general, but offer specific insights into measles and influenza vaccine hesitancy in particular.

The studies assess major determinants of vaccination (the 5C psychological determinants) – drawing on a validated methodology – but in addition explore other barriers and drivers to vaccination. We looked at different HCW populations in different settings and explored their specificities with regards to vaccination. We assessed HCWs' views about the impact of vaccine mandates and discussed why mandates are deemed apt and which findings suggest to be careful with these interventions, i.e., their potential unintended consequences. Thus, in accordance with the TIP approach, this dissertation aims to be a comprehensive assessment of vaccine hesitancy among HCWs in Germany. A strength of this dissertation is that it generates evidence pointing towards specific policy actions. Thus, this research can eventually help improving the German immunization program and can contribute to reaching important public health goals.

1.6.1 Barriers and drivers to vaccination among healthcare workers in different settings

HCWs' vaccination behaviors are associated with various psychological determinants and additional barriers. Notably, our research confirms that HCWs differ little from the general population with regard to psychological determinants of vaccination (71). We found that especially confidence in vaccines (safety and efficacy) can leverage HCWs' own vaccination behavior and recommendation behavior. We provide additional evidence that confidence in the institutions that recommend and provide vaccines constitutes a driver to vaccination. This is in accordance with previous research (21) and has been the focus of much research on vaccine hesitancy (72, 73). Confidence is generally difficult to address. Primarily it can be addressed by debunking myths (74) about vaccines and by strengthening trust in health authorities and HCWs (22, 75). Building trust, however, is a lengthy endeavor that commands actors to continuously prove trustworthy by showing among others competence, objectivity, consistency, and sincerity (76). Though increasing confidence is important, there might be more effective and faster approaches for changing vaccination behavior (50). In this dissertation we find evidence that – beyond confidence – collective responsibility, constraints and complacency are additional factors associated with HCWs' own vaccination behavior. That is, HCWs get vaccinated also to protect others, because they perceive getting vaccinated as effortless, and because they perceive the risks of vaccine preventable diseases as high.

These findings pave the way for a variety of interventions to increase vaccination rates among HCWs. First, framing vaccination as a collective responsibility, e.g., the elimination of measles as a common effort and vaccination as a way to protect those who cannot protect themselves (77). Second, developing informational interventions which raise awareness, the

perceived risk of disease and the visibility of the topic (22). Third, making vaccination more convenient, e.g., by more flexible and worksite delivery of vaccines in hospitals (78) or structural interventions such as incentives and opt-out regulations (22). This is in direct accordance with findings from study 2, namely that hospital physicians primarily don't get vaccinated against influenza because of constraints. Concerning physicians as vaccine providers, a broader use of office-based reminder systems might help – a minority has them even though they are proven effective (79) – as well as a reduction of system-related barriers (such as problems with cost coverage and vaccine shortage) – which are widely spread.

In addition, we found evidence for vaccine hesitancy being vaccine-specific and context-specific, confirming the need to tailor interventions on individual vaccines or contexts. Specifically, we find that HCWs don't recommend the measles vaccine to adults, because they forget about it – possibly because adults are only recommended to get vaccinated against measles since 2010 (80) – which suggests raising awareness of the problem (i.e., immunization gaps in adults and the respective STIKO recommendation) or introducing a reminder system could help. HCWs don't recommend the influenza vaccine because they think it is not effective (a confidence issue); they might benefit from the information that – although the vaccine efficacy is moderate and vaccination coverage low – the vaccine has still prevented on average an estimated 400,000 influenza cases per year among the elderly (81). Also, interventions trying to increase influenza vaccination coverage among hospital staff should have multiple components, acknowledging that staff show both a lack of confidence (nurses) on the one hand, potentially rooted in misinformation as results from study 2 shows (25% of nurses believe that they can become infected with the influenza virus from the vaccine), and constraints (physicians) on the other hand.

1.6.2 Healthcare workers' vaccination behavior in different settings

Only 60% of FPs indicated to be vaccinated as recommended by STIKO, thus relevant vaccination gaps exist among FPs. This underlines that there is relevant vaccine hesitancy among physicians in Germany. The same was seen in hospital staff, where relevant vaccination gaps existed for influenza and measles vaccine, with strong differences between occupational groups. It merits further investigation why nurses differ so strongly from physicians with regard to their vaccination attitudes, beliefs and behaviors. We further observed a trend in hospital staff's influenza vaccination coverage, which was low, but increased in 2018/19. This might be explained by an unusual influenza season 2017/18, the most severe influenza season in years with high numbers of hospitalizations (11), which

potentially raised awareness and risk-perception. Vaccination coverage starkly varies between vaccines, e.g., both FPs and hospital staff accept the influenza vaccine less than the hepatitis B vaccine. We observed a regional pattern, with lower vaccination coverage among FPs and hospital nurses in western than in eastern Germany. This finding has been reported also from previous studies (41, 48). Vaccination behaviors and practices have been shaped historically by different political systems in eastern and western Germany. Post-socialist regions might exhibit a different kind of respect of authority decisions and recommendations, the 5C psychological determinants, however, do not explain these differences. Vaccination coverage was also lower among FPs with a homeopathic affiliation, which underlines that certain health beliefs are associated with vaccine hesitancy (24, 82).

A large majority of FPs actively recommends vaccines to patients and less than 1% indicates to usually advice against the respective vaccines. Thus, among FPs there are few who overtly indicate to discourage their patients from vaccination. This does not tell, however, whether those patients, who receive a recommendation, actually get vaccinated. There might be other barriers, both from the recipient and provider side, that impede vaccination even though the respective vaccine was recommended. Moreover, our data does not allow to conclude what active recommendation implies for the respective FP and how the patient-provider conversation on the vaccine recommendation is carried out.

1.6.3 Attitudes towards vaccine mandates

A large majority of physicians in Germany was in favor of vaccine mandates in general and the measles vaccine mandate specifically. However, as physicians are relevant stakeholders and the ones who should implement the mandate, investigating the attitudes and beliefs of those who do not endorse the mandate is merited. Notably, pediatricians, i.e., those physicians who primarily vaccinate children against measles, were less in favor of a measles vaccine mandate compared to other physician subgroups. We found that the more physicians expected negative consequences of the mandate (a worsening of patient-provider relationships) the more they had negative attitudes towards mandates. Further on, whether or not physicians believed a mandate to be effective in increasing vaccination coverage affects their attitude towards the mandate. In pediatricians, this belief fully explains their less positive attitude towards the mandate.

These results make clear that an evaluation of vaccine mandates is needed to enable an evidence-based discussion and identify potential shortfalls of the mandates and ways to sidestep them. This refers to vaccine mandates generally, as well as the newly implemented

measles vaccine mandate in Germany in particular. The evaluation should consider physicians' reservations and should further investigate tools already used by pediatricians to increase vaccine uptake (e.g., reminder systems).

In addition, we observed that three of the five psychological determinants (confidence, collective responsibility, complacency), which explained vaccination behavior in study 1 and study 2, were also predictors of the attitude towards vaccination mandates. Thus, efforts that strengthen vaccine confidence, that appeal to collective responsibility and that fight complacency will both motivate HCWs to get vaccinated or provide vaccination and it will foster a more favorable attitude towards vaccine mandates. This shows that general efforts to strengthen vaccine demand in Germany are intertwined with approaches that aim to bring about a friendly reception of a vaccine mandate. With regards to vaccine mandates this underlines, as Hollmeyer et al. point out, that "a mandatory program must not be used as the easy, administrative magic bullet, but needs at least contemporaneous or even better antecedent implementation of a multifaceted program (…) to maximize chances for a 'friendly reception' of the policy (78)". Such programs might also be able to counter the unintended consequences of vaccine mandates. Different experimental research shows that as a response to mandates, willingness to vaccinate against diseases where vaccination remained voluntary might decline (59-61). Communicating collective responsibility can mitigate potential negative effects of vaccines mandates (61). Attwell et al. compare different strategies to manufacture consent for a vaccine mandate and find that Australia has successfully appealed to collective responsibility in their communication around the mandate, while France invested in making processes transparent and providing comprehensive in detail information thus building trust in authorities, that should appear competent, objective and sincere (83). In Germany, communication activities around the new measles vaccine mandate were initiated shortly before the mandate came into effect – consisting mainly of the establishment of a central website www.masernschutz.de. However, activities were upstaged by the COVID-19 pandemic.

In their role as vaccine providers, HCWs have conversations with patients, who are subject to the vaccine mandate. Physicians vary in their ability and their confidence in the ability to communicate with patients about vaccines. We find that physicians who felt confident in communicating with patients about vaccines had a more positive attitude towards mandates. Hence, fostering physicians' communication capabilities, e.g., by offering teaching programs about promising techniques such as motivational interviewing (30), is another

approach that possibly increases a vaccine mandate's success. Doing so will contribute both to a better reception of this policy and a strengthening of the immunization system in general.

1.6.4 Limitations

Some limitations need to be acknowledged. All studies rely on the accuracy of the self-reported data and did not control for social desirability. The studies were conducted on behalf of the national public health authority in Germany, namely the Robert Koch Institute, which might have enhanced social desirability, possibly leading to e.g., an underestimation of vaccine hesitancy and an overestimation of vaccine uptake or a more favorable attitude towards vaccine mandates. There might be a selection bias in that those more engaged in the topic, either pro-vaccine or vaccine hesitant, might have been more likely to participate. By incentivizing participation via voucher or donation to charity (study 1) or a lottery (study 2, study 3), we tried to encourage participation and reduce selection bias. For study 3, it was unknown how many physicians were reached with questionnaires (mixed-mode online/offline), hence we were not able to calculate a response rate.

1.6.5 Conclusion

Vaccines are effective only if people get vaccinated. The production of sufficient, safe and effective vaccines is only one element in a strong immunization program. Immunization programs can fail, because the implementation fails or because people are vaccine hesitant. Reasons not to vaccinate are multifaceted and go beyond confidence issues, and there might be considerable differences by target group, vaccine and setting. Therefore, immunization programs need tailoring, this means starting with a problem analysis: Which vaccination coverage is worrying and in which target group? What are the determinants of vaccination behavior in this target group? Interventions trying to increase vaccine uptake should build upon this problem analysis.

A strong immunization system heavily relies on HCWs' positive attitudes towards vaccines. However, in this thesis we found that there is considerable vaccine hesitancy among HCWs in Germany. This hesitancy is reflected by relevant vaccination gaps that exists in both private physicians and hospital staff. These vary by vaccine (measles, influenza), by context (hospital, private practice) and by population (nurses, physicians). We found that HCWs do not differ much from the general population in their reasons not to get vaccinated. Thus, it is not surprising to find that in the current COVID-19 pandemic, HCWs were as hesitant to get vaccinated against COVID-19 as the general population (12).

Tackling HCWs' vaccine hesitancy, this thesis suggests, might be achieved by different routes of intervention: improving confidence in the safety and efficacy of vaccine and the systems that deliver them; making access to vaccines more convenient in different settings (hospital, private practice); raising awareness and risk-perception for vaccine preventable diseases, therefore shifting the debate from the question whether the vaccine is effective and safe to the question why certain vaccines are recommended from the beginning on (84).

Aiming to increase measles vaccination coverage, Germany has decided to introduce a vaccine mandate. HCWs as the ones implementing the mandate play a critical role in its success. While HCWs are predominantly in favor of vaccine mandates, some reservations can be found, also with regards to the expected effectiveness of such a mandate. We find that psychological determinants for vaccination behavior and attitude towards vaccine mandates overlap. Hence interventions addressing confidence, collective responsibility and complacency will both motivate vaccination behavior and foster a friendly reception of a mandate. A vaccine mandate should be accompanied by such interventions in order to avoid potential detrimental effects of mandates. A vaccine mandate should further be evaluated regarding its outcomes.

Currently, with the COVID-19 vaccination campaign – the largest vaccination campaign in Germany in recent decades – vaccine hesitancy has become a pressing concern for policy makers and public health authorities. While vaccine supply and access to vaccination is still limited as of writing this thesis, there is already evidence of a lack of confidence in safety and efficacy of the new vaccines being rolled out, of institutional mistrust, and complacency with regard to COVID-19 (12). This thesis offers insights into barriers and drivers to vaccination and into approaches to strengthen the immunization system now and for future challenges to come.

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2 Eidesstattliche Versicherung

„Ich, Julia Friederike Pia Neufeind, versichere an Eides statt durch meine eigenhändige Unterschrift, dass ich die vorgelegte Dissertation mit dem Thema „Barriers and drivers to vaccination among healthcare workers in Germany“ (Deutscher Titel: „Hemmende und fördernde Faktoren für das Impfen bei medizinischem Personal in Deutschland“) selbstständig und ohne nicht offengelegte Hilfe Dritter verfasst und keine anderen als die angegebenen Quellen und Hilfsmittel genutzt habe.

Alle Stellen, die wörtlich oder dem Sinne nach auf Publikationen oder Vorträgen anderer Autor*innen beruhen, sind als solche in korrekter Zitierung kenntlich gemacht. Die Abschnitte zu Methodik (insbesondere praktische Arbeiten, statistische Aufarbeitung) und Resultaten (insbesondere Abbildungen, Graphiken und Tabellen) werden von mir verantwortet.

Ich versichere ferner, dass ich die in Zusammenarbeit mit anderen Personen generierten Daten, Datenauswertungen und Schlussfolgerungen korrekt gekennzeichnet und meinen eigenen Beitrag sowie die Beiträge anderer Personen korrekt kenntlich gemacht habe (siehe Anteilserklärung). Texte oder Textteile, die gemeinsam mit anderen erstellt oder verwendet wurden, habe ich korrekt kenntlich gemacht.

Meine Anteile an etwaigen Publikationen zu dieser Dissertation entsprechen denen, die in der untenstehenden gemeinsamen Erklärung mit dem Erstbetreuer angegeben sind. Für sämtliche im Rahmen der Dissertation entstandenen Publikationen wurden die Richtlinien des ICMJE (International Committee of Medical Journal Editors; www.icmje.og) zur Autorenschaft eingehalten. Ich erkläre ferner, dass ich mich zur Einhaltung der Satzung der Charité – Universitätsmedizin Berlin zur Sicherung Guter Wissenschaftlicher Praxis verpflichte.

Weiterhin versichere ich, dass ich diese Dissertation weder in gleicher noch in ähnlicher Form bereits an einer anderen Fakultät eingereicht habe.

Die Bedeutung dieser eidesstattlichen Versicherung und die strafrechtlichen Folgen einer unwahren eidesstattlichen Versicherung (§§156, 161 des Strafgesetzbuches) sind mir bekannt und bewusst.“

Datum Unterschrift

3 Anteilserklärung an den erfolgten Publikationen

Julia Friederike Pia Neufeind hatte folgenden Anteil an den folgenden Publikationen:

Publikation 1:

Neufeind J, Betsch C, Habersaat KB, Eckardt M, Schmid P, Wichmann O. Barriers and drivers to adult vaccination among family physicians – Insights for tailoring the immunization program in Germany. *Vaccine.* 2020;38(27):4252-62.

Anteil an der Publikation: 90%

- Planung des Studiendesigns
- Durchführung der Literaturrecherche und Auswahl der relevanten Literatur
- Prüfung der Daten auf Vollständigkeit und Plausibilität
- Durchführung aller Analysen – mit Ausnahme der Conditional Inference Trees (Abbildung 6)
- Erstellung aller Inhalte der Tabellen und Grafiken und deren Erzeugung
- Federführung bei Diskussion und Interpretation der Ergebnisse in Zusammenarbeit mit den Co-Autor*innen
- Federführung bei der Konzeption und Erstellung der Publikation

Publikation 2:

Neufeind J, Wenchel R, Boedeker B, Wicker S, Wichmann O. Monitoring influenza vaccination coverage and acceptance among health-care workers in German hospitals - results from three seasons. *Human Vaccine & Immunotherapeutics*. 2020;17(3):664-672.

Anteil an der Publikation: 70%

- Planung des Studiendesigns gemeinsam mit den Co-Autor*innen
- Durchführung der Literaturrecherche und Auswahl der relevanten Literatur
- Prüfung der Daten auf Vollständigkeit und Plausibilität
- Durchführung aller Analysen

- Erstellung aller Inhalte der Tabellen und Grafiken und deren Erzeugung
- Federführung bei Diskussion und Interpretation der Ergebnisse in Zusammenarbeit mit den Co-Autor*innen
- Federführung bei der Konzeption und Erstellung der Publikation

Publikation 3:

Neufeind J, Betsch C, Zylka-Menhorn V, Wichmann O. Determinants of physician attitudes towards the new selective measles vaccine mandate in Germany. *BMC Public Health*. 2021;21(1):566.

Anteil an der Publikation: 90%

- Planung des Studiendesigns
- Durchführung der Literaturrecherche und Auswahl der relevanten Literatur
- Prüfung der Daten auf Vollständigkeit und Plausibilität
- Durchführung aller Analysen
- Erstellung aller Inhalte der Tabellen und Grafiken und deren Erzeugung
- Federführung bei Diskussion und Interpretation der Ergebnisse in Zusammenarbeit mit den Co-Autor*innen
- Federführung bei der Konzeption und Erstellung der Publikation

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Unterschrift, Datum und Stempel des erstbetreuenden Hochschullehrers

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Unterschrift der Doktorandin

4 Ausgewählte Publikationen

4.1 Publikation 1

Neufeind J, Betsch C, Habersaat KB, Eckardt M, Schmid P, Wichmann O. Barriers and drivers to adult vaccination among family physicians – Insights for tailoring the immunization program in Germany. *Vaccine.* 2020;38(27):4252-62.

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4.2 Publikation 2

Neufeind J, Wenchel R, Boedeker B, Wicker S, Wichmann O. Monitoring influenza vaccination coverage and acceptance among health-care workers in German hospitals - results from three seasons. *Human Vaccines & Immunotherapeutics.* 2020;17(3):664-72.

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Neufeind J, Wenchel R, Boedeker B, Wicker S, Wichmann O. Monitoring influenza vaccination coverage and acceptance among health-care workers in German hospitals - results from three seasons. *Human Vaccines & Immunotherapeutics.* 2020;17(3):664-72. https://doi.org/10.1080/21645515.2020.1801072

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4.3 Publikation 3

Neufeind J, Betsch C, Zylka-Menhorn V, Wichmann O. Determinants of physician attitudes towards the new selective measles vaccine mandate in Germany. *BMC Public Health.* 2021;21(1):566.

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BMC Public Health

RESEARCH ARTICLE Open Access

Determinants of physician attitudes towards the new selective measles vaccine mandate in Germany

Julia Neufeind[1,2*], Cornelia Betsch[3,4], Vera Zylka-Menhorn[5] and Ole Wichmann[1]

Abstract

Background: In Germany, a mandatory policy on measles vaccination came into effect in March 2020. Physicians, as the main vaccine providers, have a crucial role in implementing it. Mandatory vaccination changes the preconditions under which patient-provider communication on vaccines occurs. Physicians might or might not favor vaccine mandates depending on, among other factors, their attitudes towards vaccines and capabilities as vaccine providers. The aim of this study was to investigate in different subgroups of physicians the association between various factors and their attitudes towards a mandatory policy.

Methods: In total, 2229 physicians participated in a mixed-mode online/paper-pencil survey. Respondents were general practitioners, pediatricians, gynecologists, and internists. Primary determinants were the 5C psychological antecedents of vaccination, communication self-efficacy, patient clientele, projected consequences of the mandate and sociodemographic characteristics. Associations between outcomes and determinants were examined using linear regression analysis.

Results: Approximately 86% of physicians were in favor of the measles vaccine mandate for children. Regarding the 5C model, physicians were more in favor of vaccine mandates when they scored higher on confidence and collective responsibility, and lower on complacency and calculation. They were more in favor of vaccine mandates when they had higher communication self-efficacy and a more vaccine-positive patient clientele. Pediatricians were less in favor of mandates for children (80.0%) than other physician subgroups (87.1%). They were also less convinced that a mandate would result in more children getting vaccinated (59.3%) than other physician subgroups (78.3%). When controlled for these expected consequences, being a pediatrician no longer lowered the attitude towards the mandate.

Conclusions: Physicians in Germany are predominantly in favor of a measles vaccine mandate. Whether or not physicians believe the mandate to be effective in increasing vaccine coverage affects their attitude towards the mandate. In pediatricians, this belief explains their less positive attitude towards the mandate. In addition, physicians need adequate support to communicate well with patients, especially those who are hesitant, to booster their communication self-efficacy. To increase acceptance of vaccine mandates, the 5C model can be used, e.g., collective responsibility can be communicated, to avoid anger stemming from a negative attitude to mandates.

Keywords: Vaccine hesitancy, Measles, Mandatory vaccination, Germany, Health care workers

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Background

In March 2020, as part of the Measles Protection Act, a new mandatory policy on measles vaccination came into effect in Germany, requiring proof of measles immunization for all children and staff in childcare and schools, as well as health workers [1]. If individuals are not able to provide this proof, a variety of sanctions can be implemented: access to preschool childcare can be rejected, at school penalties up to EUR 2500 can be collected, new employment can be rejected, and employees can be deployed elsewhere. Exemptions exist for individuals with proof of naturally-acquired immunity or with medical contraindications, e.g., allergy to vaccine components. The level of enforcement of the mandate has yet to be evaluated. This is the first vaccine mandate to be implemented in Germany, at least when only considering the last decades. Historically, there have been vaccine mandates, in the 19th and beginning of the twentieth century, against smallpox and in the German Democratic Republic against a variety of diseases.

In the context of the 2018 European Council recommendation to take action against vaccine hesitancy [2], the World Health Organization (WHO) listing vaccine hesitancy as one of the ten threats to global health in 2019 [3], large outbreaks of measles in Germany and the European region [4], and new mandates in Italy [5] and France [6], discussion evolved regarding a mandatory measles vaccination policy in Germany. In the winter of 2019, the Measles Protection Act passed in the German parliament with several measures to improve the immunization system in Germany, including new regulations on disease notifications, submission of physician claims data to be included in an immunization information system, and the obligation to provide a proof of measles protection of children and specific professional groups.

Physicians in private practices have a key role in implementing this law in Germany. First and foremost, they are the ones who primarily provide vaccines to the child and adult populations in Germany and counsel patients on vaccines. Among private physicians, the main vaccine providers are pediatricians, general practitioners (GPs), internists, and gynecologists. Pediatricians provide vaccines mainly to children, while GPs, internists and gynecologists provide vaccines mainly to adults. Secondly, they are obliged by the new law to ensure that their staff is protected against measles as well. And lastly, they themselves are obliged to be vaccinated, if not born before 1970 or protected by naturally-acquired immunity. Hence, with regard to implementation, the legislator depends on provider cooperation in these three important ways. The Measles Protection Act changes the context in which physicians operate as vaccine providers. Understanding physician attitudes towards mandates is crucial if we want to understand how physicians will implement the mandate and how the mandate may affect other vaccine decisions [7]. In particular, concerns were raised that the mandate may evoke reactance among physicians who might in turn be less likely to recommend other voluntary vaccines to their patients [8].

Physicians differ in attitude towards vaccinations and these differences affect their recommendations and vaccination behaviors [9, 10]. In addition, physicians might differ in their attitudes towards mandates. A mandate drastically reduces free choice regarding vaccination decisions for their patients, their staff, and themselves. Physicians, who formerly had the task to convince patients of measles vaccination, can now refer to the mandate. This might make it easier for those who did not feel confident before in their ability to talk to patients about the vaccines and explain their value. It might also relieve physicians who face many vaccine-hesitant patients, as they can now refer to the mandate. Mandates can also set new social norms or foster pre-existing norms, thus interacting with physician attitudes towards vaccines [8]. Physicians base their own vaccine decisions, and to some extent, their vaccine recommendations, on their own confidence in vaccines and the system that delivers them, their collective responsibility (willingness to protect others), constraints (perceived barriers), complacency (not perceiving diseases as a high risk), and calculation (engagement in extensive information search). These 5C psychological determinants of vaccination behavior [11] might also be associated with physician endorsement of vaccine mandates.

We conducted a national survey among private physicians in Germany shortly before the mandate became effective. Based on the above-mentioned considerations, we first explored whether physician attitude to the mandate was associated with the 5C psychological determinants of vaccination behavior. Secondly, we explored whether communication self-efficacy and patient clientele, as well as the expected consequences of the mandate, would be associated with attitude towards the mandate.

Methods

Study population recruitment

We pursued a mixed-mode design as an online and paper questionnaire. The survey was sent out as a paper-pencil survey to 90,000 private physicians as a supplement to Deutsches Ärzteblatt, the major medical journal in Germany that is provided free of cost to all physicians. The distribution of the questionnaire was limited to GPs, internists, pediatricians, and gynecologists – the primary vaccine providers in Germany - but also occupational physicians, dermatologists, and neurologists. On the survey, a QR code and link to the online survey was provided for convenience. In addition, a link to the

online survey was sent via e-mail newsletter to subscribers of Deutsches Ärzteblatt. It is noteworthy that participation via newsletter did not require identification as a physician. In addition, the link to the online survey was posted on the respective website of the journal (for registered users). Data was obtained from January 24 to March 6, 2020. As an incentive, participants could opt into a lottery with the chance to win a tablet computer or a stethoscope.

Survey instrument

All items used (translated into English), the R code and complete survey, can be found here (https://osf.io/pbgef/). Our primary study outcome was the attitude towards vaccine mandates, assessed by four self-developed items. These included items on attitudes towards a selective measles mandate for children and health care personnel, and towards a general mandate for all vaccines recommended for children, e.g., 'the measles vaccine should be mandatory for children in school and kindergarten'. For each of these items, respondents stated their level of agreement on a five-point-Likert-scale ranging from 'strongly disagree' (score = 1) to 'strongly agree' (score = 5). We calculated a mean score for 'attitude towards mandates', consisting of four items (Cronbach's alpha = 0.88), ranging from a negative attitude towards the mandate (score = 1) to a positive attitude (score = 5). In addition, we developed items to assess physicians' projected consequences of the Measles Protection Act in their practice, e.g., 'the mandate will be a burden for the patient-provider relationship'. For each of these items, the respondents stated their level of agreement on a five-point-Likert-scale ranging from 'strongly disagree' (score = 1) to 'strongly agree' (score = 5). The 5C short scale on psychological determinants contained five items, one for each construct (confidence, collective responsibility, constraints, complacency and calculation), e.g., 'I am completely confident that vaccines are safe'. For each of these items the respondents stated their level of agreement on a five-point-Likert-Scale ranging from 'strongly disagree' (score = 1) to 'strongly agree' (score = 5) [11].

We assessed physician confidence in communicating with patients about vaccines using self-efficacy items, e.g., 'how confident are you in your ability to talk with patients and parents about vaccines?' [12]. Respondents stated their level of confidence on a five-point-Likert-scale ranging from 'not at all confident' (score = 1) to 'very confident' (score = 5). We calculated a mean score for 'communication self-efficacy', consisting of four items (Cronbach's alpha = 0.87).

Four items from a knowledge scale assessed the level of misinformation, e.g., 'vaccinations increase the occurrence of allergies' (possible answers: agree, disagree, or don't know) [13]. We calculated a sum score for 'vaccine knowledge', in which every correct answer was counted as one point and every false answer or don't know answer was counted as zero points.

We quantified patient positions on vaccination, i.e., the patient clientele, drawing on a taxonomy introduced by Leask et al. [14]. Accordingly, patients can broadly be divided into (i) unquestioning acceptors, (ii) cautious acceptors, (iii) late/selective vaccinators, and (iv) refusers. After briefly describing the characteristics, e.g., 'what is the proportion of your patients or parents who accept vaccines without questions?', we asked participants to estimate what portion of patients would fall into each category (reported as %).

Sociodemographic characteristics collected included occupational group (i.e., GP, pediatrician, gynecologist, or internist), gender, years of work experience, region (i.e., eastern or western Germany), and city size.

Beyond the measles vaccine mandate, a variety of measures to increase vaccine uptake have been discussed in Germany. As part of the Measles Protection Act, the option to pilot test the provision of influenza vaccination in pharmacies has been introduced in some regions in Germany, starting with the 2020–21 season. We asked participants whether they were in favor of the following measures (possible answers: yes, no, or don't know): vaccination in schools, vaccination in pharmacies, and introduction of a digital vaccination card for their patients.

Statistical analyses

Analyses were conducted in R [15]. Agreement to items was measured using a five-point-Likert-scale, and descriptive data was reported as: percentage who disagreed (= 1, 2), were undecided (= 3) or agreed (= 4, 5). Complete case analysis was pursued for all items. We performed blockwise multiple linear regressions to identify correlates of the attitude towards vaccine mandates. Model one contained sociodemographic characteristics, i.e., work experience, gender, region, city size, and occupational group. In the second step, 'communication self-efficacy' and 'patient clientele' were added. In the third step, the 5C psychological determinants of vaccination were added. In the fourth step, the expected consequence ('more children vaccinated') were added. We report β estimates, 95% confidence intervals (CI), and R^2 to assess model fit. We computed variance inflation factors (VIF) to test for multicollinearity and interpreted values < 5 as presenting no multicollinearity issues (there was no issue of multicollinearity in our regression models). Next, we tested for mediation of these relationships using the mediation package [16]. Our model included occupational group as the predictor variable, expected consequences of the mandate as the mediator variable, and attitude towards the mandate as the outcome variable. We further assessed differences between

pediatricians and other physician subgroups using t-tests. We assessed correlations between the attitude towards the mandate and projected consequences using Pearson's method.

Results

Response and sociodemographic characteristics

In total, 2762 physicians participated in the survey. Of these, 2467 indicated belonging to the initial survey target groups (i.e., GPs, gynecologists, internists, and pediatricians). Other medical specialists, excluded from analysis, totalled 295 of the participants. We further excluded 238 participants who received survey invitations via newsletter. Their answers differed significantly from physicians receiving other modes of invitation. Specifically, participants who used the newsletter link were significantly more vaccine hesitant (confidence, complacency) and had a high proportion of missing data (approximately 20% per variable). This led to the assumption this mode had been taken over by vaccine deniers. Furthermore, and in contrast to all other ways to enter the survey, there was no way to ensure that the participating individuals were indeed physicians. To ensure high data quality, we eventually included 2229 participants in our analysis (1140 participated via online survey and 1089 via paper-pencil survey). Among these, 1178 were GPs, 259 gynecologists, 416 internists, and 376 pediatricians. Missing values were below 5% for all items. With our final dataset, we assessed potential mode effects in our regression model, including mode of participation (paper vs. online) as a covariate, and found no significant mode effect. On average, respondents had 19 years of work experience and 54.3% were female. For further characteristics of the study population, see Table 1.

Attitude towards vaccine mandates, expected consequences of the measles mandate, and vaccine knowledge

Of the participants, 85.9 and 88.2% of physicians agreed that the measles vaccine should be mandatory for children and health care workers, respectively (5.4% and 5.1 undecided, 8.7 and 6.8% disagreed, respectively). It is noteworthy that pediatricians were less in favor of a mandate for children (80.0%, mean [M] = 4.2) than other physician subgroups (87.1%, M = 4.4, t [489] = − 3.3, $p < 0.001$); however, they were more in favor of a mandate for health care workers (92.2%, M = 4.6) than other physician subgroups (87.4%, M = 4.4, t [614] = 5.0, $p < 0.001$). Seventy percent of participants indicated that all recommended vaccines for children should be mandatory (13.3% undecided, 16.7% disagreed). Of the participants, 16.8% agreed that everybody should be able to decide freely about themselves and their children (17.4% undecided, 65.8% disagreed). The latter item was reverse-coded to build the mean score. Pediatricians were less in favor that all recommended vaccines for children should be mandatory (61.0%, M = 3.6) than other physician sub-groups (71.8%, M = 3.9, t [497] = − 4.1, $p < 0.001$) and more in favor that everybody should be able to freely decide about themselves and their children (21.1%, M = 2.4) than other physician subgroups (15.8%, M = 2.3, t [497] = 2.0, $p < 0.05$).

Table 1 Characteristics of study population

Variable	Level	Pediatrician	GP	Gynecologist	Internist	*p*-value
n		376	1178	259	416	
Gender: n (%)	Male	173 (48.2)	512 (46.0)	63 (25.6)	221 (55.1)	< 0.001
	Female	186 (51.8)	601 (54.0)	183 (74.4)	180 (44.9)	
Work experience: mean (SD)		18.68 (10.38)	20.25 (10.97)	19.35 (10.47)	16.50 (9.79)	< 0.001
Region: n (%)	Western	283 (80.2)	895 (81.4)	184 (75.7)	321 (80.2)	0.260
	Eastern	70 (19.8)	205 (18.6)	59 (24.3)	79 (19.8)	
City size: n (%)	< 10.000	41 (11.5)	397 (35.7)	27 (11.1)	64 (15.9)	< 0.001
	10.000–100.000	181 (50.8)	428 (38.5)	123 (50.4)	192 (47.6)	
	> 100.000	134 (37.6)	286 (25.7)	94 (38.5)	147 (36.5)	
Attitude towards mandates: mean (SD)[a]		4.00 (0.93)	4.03 (0.97)	4.32 (0.82)	4.19 (0.92)	< 0.001
Reported patient clientele: mean (SD)	Unquestioning acceptor	72.73 (20.49)	61.23 (22.94)	49.63 (24.25)	60.45 (20.68)	< 0.001
	Cautious acceptor	19.03 (16.47)	22.60 (16.28)	28.10 (16.62)	21.91 (14.89)	< 0.001
	Selective vaccinator	5.51 (6.58)	11.44 (11.04)	14.36 (13.14)	11.91 (10.18)	< 0.001
	Refuser	2.73 (6.26)	4.73 (5.92)	7.92 (8.66)	5.73 (5.78)	< 0.001
Communication self-efficacy: mean (SD)[b]		4.49 (0.58)	4.24 (0.63)	4.26 (0.61)	4.22 (0.66)	< 0.001
Vaccine knowledge: mean (SD)[c]		3.85 (0.50)	3.61 (0.86)	3.67 (0.73)	3.70 (0.70)	< 0.001

[a]Mean score 'attitude towards mandates' consisting of four items (Cronbach's alpha = 0.88) expressing negative attitude (score = 1) to positive attitude (score = 5)
[b]Mean score 'communication self-efficacy' consisting of four items (Cronbach's alpha = 0.87) ranging from very low (score = 1) to very high (score = 5)
[c]Sum score 'vaccine knowledge' consisting of four items, every correct answer was counted as 1 point and every false answer or 'don't know' answer was counted as 0 points

The attitude towards mandates was predominantly associated with the projected consequences of the mandate for their own practice (Table 2). The strongest correlation was found for the following two items: (i) the more physicians expected that due to the new law more children would be vaccinated on time, the more they had a positive attitude towards mandates, and (ii) the more physicians expected the mandate to be a burden for the patient-provider relationship, the more they had a negative attitude towards mandates.

Pediatricians predominantly expected more negative consequences of the mandates for their own practice than other physician subgroups (Table 2). The largest difference was found for the expected vaccine uptake, as significantly less pediatricians (59.3%) than other physician subgroups (78.3%) expected more children to be vaccinated on time. Also, significantly more pediatricians than other physician subgroups expected the mandate to be a burden for the patient-provider relationship. Among participants, there was a wide spread of opinions on whether or not they expected consequences from the mandate for their own practice (44.1% agreed, 20.3% were undecided, 35.7% disagreed). Similarly, physicians were divided on whether or not counseling patients would require more effort (46.3% agreed, 23.3% undecided, 30.4% disagreed). Only 7.1% indicated that the mandate would lead to less effort in vaccine counseling (13.3% undecided, 79.5% disagreed). Of the participants, 48.2% expected a higher amount of work for issuing certificates on measles protection to patients (17.1% undecided, 34.7% disagreed), and 16.0% expected that patients would press them to issue medical exemptions from the mandate (18.8% undecided, 65.2% disagreed).

With regard to vaccine knowledge, 79.6% of participants answered all items correctly. Only among 1.3% of participants were all answers false. On average, participants had scores of 3–4 out of 4 correct answers (M = 3.6, standard deviation [SD] =0.77). Vaccine knowledge differed significantly among occupational groups (Table 1), with pediatricians exhibiting more knowledge (M = 3.85) than other physician sub-groups (M = 3.64, t [803] = 6.7, $p < 0.001$).

Correlates of the attitude towards the mandatory policy

Table 3 presents results of a series of stepwise regressions predicting the attitude towards the measles mandate. Region, work experience, occupational group, communication self-efficacy, patient clientele, the 5C psychological determinants, and whether more children were expected to be vaccinated on time were associated with attitude towards mandates. Physicians from eastern Germany and those with more years of work experience had more positive attitudes towards vaccine mandates. The higher the communication self-efficacy and the more patients were unquestioning acceptors, the more physicians had positive attitudes towards vaccine mandates. Physicians had more positive attitudes towards the vaccine mandate the higher their confidence or collective responsibility, and the lower their complacency or calculation. Being a pediatrician was associated with a more negative attitude towards mandates. The coefficients increased when communication self-efficacy and patient clientele were added to the model and remained stable when the 5C determinants were added. When the expected consequence 'more children vaccinated' was added, the coefficients became insignificant (GPs and

Table 2 Expected consequences of the mandate and correlation with attitude towards mandates for pediatricians vs. others

Expected consequences of mandate	Mean (SD)[a]			Correlation[b] with attitude towards mandates[c]	
	Pediatricians	Other physicians	*p*-value	Pediatricians	Other physicians
I expect no consequences.	**2.97 (1.29)**	**3.16 (1.33)**	0.014	**0.11**	**0.09**
Counseling patients will require more effort.	**3.01 (1.13)**	**3.23 (1.09)**	0.001	**−0.16**	**− 0.15**
Counseling patients will require less effort.	2.01 (0.96)	1.94 (0.87)	0.203	**0.17**	**0.12**
The mandate will be a burden for the patient provider relationship.	**2.11 (0.95)**	**1.98 (0.97)**	0.018	**−0.34**	**− 0.35**
I expect a higher amount of work for issuing certificates about measles protection to patients.	**2.47 (1.12)**	**2.33 (1.00)**	0.017	**−0.19**	**−0.24**
I expect that patients will press me to issue medical exemptions from the mandate.	**3.38 (1.24)**	**3.16 (1.26)**	0.003	−0.04	**−0.19**
I expect more children to be vaccinated on time.	**3.47 (1.06)**	**3.93 (0.90)**	< 0.001	**0.25**	**0.35**

Bold denotes significance at $p < 0.05$.
[a]Likert scale items (1 = disagree; 5 = strongly agree)
[b]Pearson's method
[c]Mean score 'attitude towards mandates' consisting of four items (Cronbach's alpha = 0.88) expressing negative attitude (score = 1) to positive attitude (score = 5)

Table 3 Multiple linear regression models for attitudes towards vaccine mandates[a]

		Model 1	Model 2	Model 3	Model 4
Explanatory variables		β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)
(Intercept)		3.80 (3.64–3.95)	2.45 (2.11–2.80)	1.52 (0.92–2.11)	0.91 (0.33–1.49)
Region	Western	*Reference*	*Reference*	*Reference*	*Reference*
	Eastern	**0.26 (0.16–0.37)**	**0.25 (0.15–0.35)**	**0.23 (0.14–0.33)**	**0.26 (0.16–0.35)**
Gender	Male	*Reference*	*Reference*	*Reference*	*Reference*
	Female	0.05 (− 0.03–0.14)	**0.09 (0.01–0.18)**	0.04 (− 0.04–0.12)	− 0.00 (− 0.08–0.07)
City size	< 10.000	*Reference*	*Reference*	*Reference*	*Reference*
	10.000–100.000	−0.03 (− 0.14–0.07)	−0.01 (− 0.12–0.09)	−0.02 (− 0.11–0.08)	−0.01 (− 0.11–0.08)
	> 100.000	− 0.03 (− 0.15–0.08)	−0.02 (− 0.13–0.09)	−0.02 (− 0.12–0.08)	−0.04 (− 0.14–0.05)
Work experience		**0.01 (0.00–0.01)**	**0.01 (0.00–0.01)**	**0.01 (0.00–0.01)**	**0.01 (0.00–0.01)**
Occupational group	Pediatrician	*Reference*	*Reference*	*Reference*	*Reference*
	GP	0.01 (−0.10–0.13)	**0.13 (0.01–0.24)**	**0.14 (0.04–0.25)**	0.02 (−0.08–0.13)
	Gynecologist	**0.30 (0.14–0.45)**	**0.45 (0.29–0.61)**	**0.33 (0.18–0.47)**	**0.19 (0.04–0.33)**
	Internist	**0.20 (0.06–0.33)**	**0.31 (0.18–0.45)**	**0.25 (0.12–0.37)**	0.11 (−0.01–0.24)
Communication self-efficacy[b]			**0.22 (0.16–0.29)**	**0.11 (0.05–0.18)**	**0.10 (0.04–0.16)**
Patient clientele[c]			**0.45 (0.27–0.64)**	0.16 (− 0.01–0.33)	0.14 (− 0.02–0.31)
Confidence				**0.40 (0.34–0.46)**	**0.35 (0.29–0.41)**
Collective responsibility				**0.10 (0.02–0.19)**	**0.12 (0.04–0.20)**
Constraints				−0.04 (−0.09–0.01)	−0.04 (− 0.09–0.01)
Complacency				**−0.32 (− 0.42– − 0.22)**	**−0.28 (− 0.38– − 0.18)**
Calculation				**−0.09 (− 0.12– − 0.06)**	**−0.09 (− 0.11– − 0.06)**
More children vaccinated[d]					**0.25 (0.21–0.29)**
Observations		1974	1974	1974	1974
R^2/R^2 adjusted		0.034/0.030	0.069/0.064	0.219/0.213	0.277/0.271

Blockwise inclusion of covariates in Model 1, Model 2, and Model 3
Bold denotes significance at $p < 0.05$
[a]Mean score 'attitude towards mandates' consisting of four items (Cronbach's alpha = 0.88) expressing a negative attitude (score = 1) to a positive attitude (score = 5)
[b]Mean score 'communication self-efficacy' consisting of four items (Cronbach's alpha = 0.87) ranging from very low (score = 1) to very high (score = 5)
[c]'Patient clientele' as portion of patients who are unquestioning acceptors of vaccination ranging from 0 (0%) to 1 (100%)
[d]Expected consequence of the mandate, item: 'I expect more children to be vaccinated on time' (1 = disagree; 5 = strongly agree)

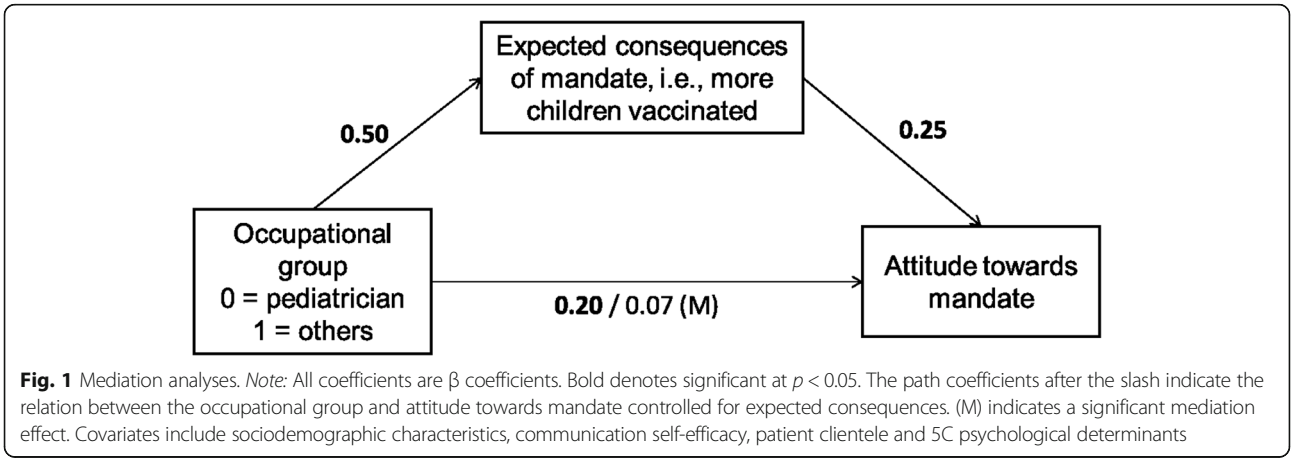

Fig. 1 Mediation analyses. *Note:* All coefficients are β coefficients. Bold denotes significant at $p < 0.05$. The path coefficients after the slash indicate the relation between the occupational group and attitude towards mandate controlled for expected consequences. (M) indicates a significant mediation effect. Covariates include sociodemographic characteristics, communication self-efficacy, patient clientele and 5C psychological determinants

internists) or decreased (gynecologists), i.e., the degree to which participants expected the mandate to increase vaccine uptake among children, and provided an explanation for the difference in attitude towards the mandate between physician subgroups. We explored this effect in mediation analysis.

Figure 1 depicts the mediation model used to test whether the expected consequences of the mandate for their own practice mediate the effect of occupational group on the attitude towards the mandate (see Supplementary Table 1 also). We included sociodemographic characteristics, communication self-efficacy, patient clientele, and the 5C determinants as covariates. Not being a pediatrician significantly increased the attitude towards the mandate, which was completely mediated by an increased belief in expected consequences for their own practice, i.e., more children being vaccinated on time (Average Causal Mediation Effect [ACME]: $\beta = 0.13$, 95% CI = 0.09–0.17, $p < 0.05$). Thus, a complete mediation effect occurred. When controlling for the expected consequences, being a pediatrician no longer lowered the attitude towards the mandate.

Two-thirds of physicians were in favor of vaccination programs in schools (61.5% endorsed, 30.9% rejected, 7.6% undecided). Only 4.3% endorsed the vaccination in pharmacies (91.8% rejected, 3.9% undecided). The majority endorsed the introduction of a digital vaccination cards (58.1% endorsed, 21.7% rejected, 20.2% undecided).

Discussion

The Measles Protection Act was initiated by the Ministry of Health in May 2019 in a political and societal climate of broad acknowledgement that something had to be done to strengthen the national immunization program and to fight vaccine hesitancy in Germany [17]. Former plans to eliminate measles by 2015 had failed [18]. Vaccination coverage for children was high (> 95% MCV1), but vaccination was often delayed and incomplete [19]. Furthermore, considerable vaccination gaps were identified among young adults (80% coverage for adults aged 18–29 years, 47% for those aged 30–39 years) [20]. A mandate was considered to be one option among others to increase vaccine uptake and as such both the governing parties and medical societies as well as other stakeholders supported it [21–23]. Some stakeholders, however, expressed concerns regarding the legal, sociological and ethical dimension of such a mandate, e.g. the German Ethics Council [24]. Moreover, potential psychological consequences were discussed, such as detrimental effects on the willingness to vaccinate against diseases where vaccination remained voluntary [25–27]. The result of the controversy was a law that encompassed - beyond a mandate - different aspects to strengthen the immunization system in Germany [1]. This study aimed at understanding physicians' attitudes towards vaccine mandates shortly before the introduction of the law.

A large majority of the private physicians who participated in our survey were in favor of the new measles vaccination mandate and had a positive attitude towards vaccine mandates in general. However, pediatricians, i.e., those physicians who primarily vaccinate children against measles, were less in favor of a measles vaccine mandate compared to other physician subgroups. The more participants expected negative consequences of the mandate for their own practice, e.g., more work or a burden for patient-provider relationships, the more they had negative attitudes towards mandates.

We assumed that physicians who regularly encountered difficulties in vaccine counseling would have a positive attitude towards the mandate, as the mandate might eliminate their role in discussing the rationale for the measles vaccine. However, in our study, we observed the contrary. Physicians had a more negative attitude towards the mandate when they had lower confidence in communicating with patients about vaccines, i.e., lower communication self-efficacy and a lower proportion of unquestioning acceptors among their patients. In contrast, physicians who felt higher communication self-efficacy and who had more unquestioning acceptors among their patient clientele were more likely to endorse vaccine mandates.

Among the psychological determinants, a more negative attitude towards the mandate was associated with lower vaccine confidence, lower collective responsibility, higher complacency, and higher calculation, while no effect was found for constraints. With regard to confidence, we assume that when physicians question vaccine safety, mandatory vaccines appear worrisome, as vaccination may put the vaccinated person at risk for potentially adverse events. From an ethical perspective, a mandate violates individual liberty, i.e., free will, but this violation may be justified as long as the mandate maximizes individual health. Those who lack confidence in vaccine safety, however, may question this benefit to individual health [28]. Likewise, a French study conducted shortly before the implementation of new vaccine mandates in France found fear of side-effects to be associated with a more negative attitude towards mandates among the general population [29]. In an Italian study pregnant women were more likely to favor vaccine mandates when they felt that health professionals were honest to them about the risk of vaccines [30]. With regard to collective responsibility, we believe that physicians who vaccinate themselves and others in order to protect others could favor a mandate, because a mandate restricts individual liberty in order to protect others. In contrast, physicians who vaccinate for self-protection only (low

collective responsibility) will be more willing to take advantage when enough others are vaccinated and thus, might oppose a mandate, as their personal risk of infection is relatively low [31]. In accordance with this, an Australian study among health care workers found that the protection of co-workers was among the primary reasons for supporting an influenza vaccine mandate [32]. With regard to complacency, we suggest that when risk perception is high enough, more drastic measures seem acceptable. The above-mentioned French study found that the perception that vaccines bring important health benefits was associated with a more positive attitude towards mandates [29]. In our study, participants with high calculation were more likely to have a negative attitude towards vaccine mandates. Individuals with high calculation base their decisions on utility maximization, i.e., engaging in extensive information seeking and attempting to make the best decision for themselves [8]. In previous studies, it was shown that calculation is associated with non-vaccination [11]. Physicians high on calculation might see their freedom to take these selfish, rational decisions infringed by a vaccination mandate [26].

Pediatricians had more negative attitudes towards vaccine mandates (especially mandates for children) than other physician subgroups. Pediatricians were also less confident that more children would be vaccinated due to the mandate than other physician subgroups. Thus, those physicians who have the most experience in vaccinating children were less in favor of a measles mandate for children and less convinced it would successfully increase coverage. We found that not being a pediatrician increased the perception that more children would be vaccinated (expected consequence), which in turn increased a positive attitude towards mandates (mediation effect). At the same time, pediatricians were better informed about vaccine safety (vaccine knowledge), and had a higher communication self-efficacy and more unquestioning acceptors among their patients.

Some limitations of our study need to be acknowledged. The survey does not control for social desirability. The survey was conducted, among others, on behalf of the national public health authority in Germany, which might have enhanced social desirability, possibly leading to an overestimation of a favorable attitude towards vaccine mandates and vaccines, in general. Since it is unknown how many physicians we reached with questionnaires (mixed-mode online/offline), we were not able to calculate a response rate. There might be a selection bias in that those more engaged in the topic, either pro-vaccine or vaccine hesitant, might have been more likely to participate. By incentivizing participation through a lottery, we tried to encourage participation and reduce selection bias. Due to our study design we were unable to determine whether our survey population is representative of Germany's primary care providers. We could show, however, that the distribution of gender and region in our study population was similar to the distribution of gender and region among physicians in Germany (Supplementary Table 2) [33]. Furthermore, the means for the 5C psychological determinants of vaccination in our study (GPs only) were very similar to a comparable study among German family physicians which used random sampling (data collection 2017/18) [34].

There are few studies that evaluate determinants of attitudes towards vaccine mandates [35, 36]. A systematic review on attitudes towards vaccine mandates found varying degrees of approval of vaccine mandates in different countries and different populations. However, the authors conclude that few studies go beyond a mere description of approval rates to the respective mandates and suggest that further studies should investigate the determinants of attitudes towards mandates [37]. Our study contributes to filling this knowledge gaps. A follow-up study is planned for 2022 to assess whether physician attitudes towards vaccine mandates have changed and whether expected consequences occurred. As part of a larger research project evaluating the measles vaccine mandate in Germany, a longitudinal survey study among parents has been initiated in August 2020.

Conclusions

Shortly before the introduction of a measles vaccine mandate in Germany, the majority of physicians were in favor of the mandate and vaccine mandates, in general. The attitudes, however, differed. This study identified determinants of these attitudes and hence has implications for policy and further research:

Pediatricians, even though well-versed vaccine providers, were more hesitant towards the mandates, especially for the group of patients they serve – children. Their lack of confidence in the ability of the mandate to increase vaccine coverage among children explains their hesitancy towards mandates. Given their high expertise as vaccine providers, their concern deserves further investigation. Evaluation of the vaccine mandate and its effects on vaccine uptake and vaccine hesitancy is needed - not only for this reason - to enable an evidence-based discussion. This includes investigation into other tools used by pediatricians to increase vaccine uptake (e.g. reminder systems).

In addition, negative attitudes on mandates occur among physicians with lower communication self-efficacy and higher numbers of vaccine hesitant patients. Therefore, physicians need adequate support to communicate well with patients, especially hesitant patients. This includes offering training for physicians in doctor-patient conversation, e.g. applying promising techniques

such as motivational interviewing [38], and making vaccination more prominent in medical training at university.

Our study suggests that physicians who have low confidence in vaccination, low collective responsibility and high complacency have a more negative attitude towards mandates, and might react with anger, similar to an effect observed in patients [26, 27]. It remains unclear which consequences anger could have on both physicians and patients. Public health institutions can try to prevent anger by communicating herd protection, thus countering detrimental effects of vaccine mandates, e.g., lower vaccine uptake for other voluntary vaccines [27]. This means that– in all communication activities - vaccination is framed as a collective responsibility, elimination of measles as a common effort, and vaccination as a way to protect those who cannot protect themselves [39]. Furthermore, public health institutions should invest more in transparency concerning vaccine safety and effective communication of the risks of vaccine-preventable diseases, e.g., the resurgence of measles, if they want to maintain physician support in vaccine mandates. This involves making vaccine safety monitoring data more accessible to laypersons, and debunking vaccine safety myths [40].

Whether or not mandates are effective in increasing measles vaccine uptake in Germany is yet to be evaluated. Omer et al. have argued that mandates can be effective if implemented with care and consideration of context [25]. Physician support of mandates, however, cannot be taken for granted.

Abbreviations

GP: General practitioner; ACME: Average Causal Mediation Effect; M: Mean; WHO: World Health Organization; SD: Standard deviation; CI: Confidence interval; VIF: Variance inflation factor

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12889-021-10563-9.

Additional file 1: Supplementary Table 1. Title: Mediation analyses: Effect of occupational group (X) on attitude towards mandates (Y) via expected consequences (M). **Supplementary Table 2.** Title: Sociodemographic characteristics of the study population and of physicians in Germany

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Authors' contributions

JN contributed to the conception, design, analysis, interpretation of data, and drafted the work. OW and CB contributed to the conception, design, interpretation of data, and substantively revised the draft manuscript. VZK contributed to conception, design, and acquisition of data. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

All methods were carried out in accordance with relevant guidelines and regulations. The Ethics Commission of the University of Erfurt approved this survey (#20191209). The anonymity of the participants was guaranteed. Before the questionnaire started, all participants provided informed consent. For participation in the lottery, e-mail addresses were collected to contact the winners and this information was saved separately from the survey data.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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Publisher's Note

5 Lebenslauf

Mein Lebenslauf wird aus datenschutzrechtlichen Gründen in der elektronischen Version meiner Arbeit nicht veröffentlicht.

Mein Lebenslauf wird aus datenschutzrechtlichen Gründen in der elektronischen Version meiner Arbeit nicht veröffentlicht.

6 Komplette Publikationsliste

6.1 Publikationen in Fachzeitschriften mit Peer-Review

Neufeind J, Betsch C, Zylka-Menhorn V, Wichmann O. Determinants of physician attitudes towards the new selective measles vaccine mandate in Germany. *BMC Public Health.* 2021;21(1):566. IF: 3,295

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6.2 Weitere Publikationen

Rieck T, **Neufeind J**, Feig M, Siedler A, Wichmann O. Inanspruchnahme von Impfungen bei Erwachsenen aus Daten der KV-Impfsurveillance. *Epidemiologisches Bulletin.* 2019;44:457-66.

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Neufeind J, Wenchel R, Bödeker B, Wichmann O. OKaPII-Studie zur Influenza-Impfung: Impfquoten und Impfmotivation bei Klinikpersonal in der Influenza-Saison 2016/2017. *Epidemiologisches Bulletin.* 2018;32:313-332.

6.3 Kongressbeiträge mit Peer-Review Verfahren

Neufeind J, Betsch C, Habersaat KB, Eckardt M, Schmid P, Wichmann O. Impfbereitschaft von Hausärztinnen und Hausärzten in Deutschland – Ergebnisse einer repräsentativen Befragung 2018 (Poster). 6. Nationale Impfkonferenz 2019, Hamburg. Tagungsband abrufbar unter: https://nationale-impfkonferenz.de/wp-content/uploads/sites/10/2019/10/Berichtsband-NIK-2019.pdf

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Neufeind J, Betsch C, Habersaat KB, Eckardt M, Schmid P, Wichmann O. Telefonische Befragung von Allgemeinmedizinern in Deutschland zur Impfakzeptanz in der hausärztlichen Versorgung mit Fokus auf Masern und Influenza (TAMIA-Studie) (Poster). 14. Kongress für Infektionskrankheiten und Tropenmedizin 2018, Köln. Tagungsband abrufbar unter: http://www.kit2018.de/assets/web_kit2018_bookofabstracts_bypresentation_authors_2018-05-30.pdf

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