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COVID-19 PREVENTION IN HEALTHCARE WORKERS THROUGH VACCINATION: ACCEPTANCE, PROCESS EVALUATION AND BEST PRACTICE CONCEPTS

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List of abbreviations

AEFIs	Adverse effects following immunization
COVID-19	Coronavirus disease
ECDC	European Centre for Disease Prevention and Control
HBM	Health Belief Model
HCWs	Healthcare workers
IMPF^{LMU}	Prospektive Studie zur Evaluierung des Impfprozesses und zur Erfassung der Impfbereitschaft von Mitarbeiter*innen am LMU Klinikum im Zuge der Covid-19 Pandemie
NPIs	Non-pharmaceutical interventions
pH1N1	Pandemic influenza A(H1N1)
SARS-CoV-2	Severe acute respiratory syndrome coronavirus 2
WHO	World Health Organization
SAGE	Strategic Advisory Group of Experts

List of publications

Paper I:

Zhelyazkova, A.; Adorjan, K.; Kim, S.; Klein, M.; Prueckner, S.; Kressirer, P.; Chouker, A.; Coenen, M.; Horster, S. Are We Prepared for the Next Pandemic? Management, Systematic Evaluation and Lessons Learned from an In-Hospital COVID-19 Vaccination Centre for Healthcare Workers. International journal of environmental research and public health 2022, 19, doi:10.3390/ijerph192316326.

Paper II:

Zhelyazkova, A.; Kim, S.; Klein, M.; Prueckner, S.; Horster, S.; Kressirer, P.; Chouker, A.; Coenen, M.; Adorjan, K. COVID-19 Vaccination Intent, Barriers and Facilitators in Healthcare Workers: Insights from a Cross-Sectional Study on 2500 Employees at LMU University Hospital in Munich, Germany. Vaccines (Basel) 2022, 10, doi:10.3390/vaccines10081231.

1. Own contribution to the publications

1.1 Contribution to the project IMPF^{LMU}

The project „Prospektive Studie zur Evaluierung des Impfprozesses und zur Erfassung der Impfbereitschaft von Mitarbeiter*innen am LMU Klinikum im Zuge der Covid-19 Pandemie“ (abbreviated IMPF^{LMU}) was established at the beginning of the COVID-19 vaccination campaign at the LMU University Hospital in Munich, Germany. The need for the project was based on the research and operational area of interest regarding the hospital’s employees’ intent to receive a COVID-19 vaccine and was further exacerbated by previously collected data at the LMU University Hospital through the All-Corona-Care study (ACC) in the second and third quarter of 2020 prior to the authorisation of any vaccine against COVID-19. ACC was designed as a cross-sectional seroprevalence study among the cohort of LMU University Hospital’s employees, where data were collected through a blood sample for determining the SARS-CoV-2 antibodies prevalence and an epidemiological questionnaire exploring factors potentially associated with infection prevalence among the cohort (N=7,554). Beyond the immediate risk factors for SARS-CoV-2 exposure or infection, the questionnaire contained the inquiry on the willingness to receive a preventive inoculation: “Would you get vaccinated against SARS-CoV-2 if there was an efficient vaccination available with few side effects?” [1]. Among study participants tested positive for SARS-CoV-2 antibodies (n=166), 85 were willing to receive an inoculation against COVID-19 upon authorisation and recommendation, while further 49 participants were decided against a possibly forthcoming inoculation and 32 reported being undecided [1]. These preliminary results as well as the impending commencement of the vaccination campaign against COVID-19 in Germany, highlighted the question of prevalence of vaccine acceptance as well as the factors potentially influencing the decision-making process towards accepting, refusing or delaying a COVID-19 inoculation.

The project IMPF^{LMU} provided the operational frame for this thesis by enabling a structured and systematic data collection. The doctoral candidate (A.Z.) and the first thesis supervisor (K.A.) are the principal investigators of the project. With direct support and supervision from K.A., A.Z. was responsible for constructing the project design, coordinating the project team, obtaining all necessary statements of approval including by the Data Protection Officer of the LMU University Hospital and the ethics committee of the medical faculty at LMU Munich (Project number: 21-0123), as well as for managing the dissemination and communication of the surveys within the project. Further, A.Z. was responsible for conducting the needed literature searches, compiling evidence, outlining the research questions for the project, and designing the data collection tools (surveys) that provided the database for both publications which are part of this thesis. A.Z. collected and integrated input from all cooperating project partners regarding the data collection tools.

Additionally, and per request, A.Z. has presented the initial results of the project to the executive board of the LMU University Hospital in the form of a descriptive report and oral presentation in December 2021. The report consisted only of descriptive data, did not include any of the inferential analyses presented in the publications included to this thesis as it had the sole purpose of providing data on the timely topic of COVID-19 vaccination willingness among the hospital's employees and their satisfaction with the vaccination centre. The report was provided solely to the members of the executive board and has not been submitted nor published anywhere.

1.2 Contribution to paper I: COVID-19 Vaccination Intent, Barriers and Facilitators in Healthcare Workers: Insights from a Cross-Sectional Study on 2500 Employees at LMU University Hospital in Munich, Germany

The doctoral candidate (A.Z.) is the first and corresponding author of this paper. A.Z. was responsible for conceptualising the project and data analysis plan for the manuscript with supervision from K.A. and consultations with S.K. That includes the design of the data collection tool (survey) as described above.

A.Z. was responsible for planning and formulating the hypotheses to be tested. Preparing and executing the statistical analysis as well as interpreting the outcomes was shared as a task between A.Z. and S.K.

Further, A.Z. was responsible for curating and visualising the data as well as for writing the original draft, collecting, and incorporating input from all co-authors. A.Z. coordinated the submission process of the manuscript including the integration of and the responses to the reviewers' comments. All co-authors provided integral input at all stages of the manuscript preparation including the review and editing of the publication draft.

1.3 Contribution to paper II: Are We Prepared for the Next Pandemic? Management, Systematic Evaluation and Lessons Learned from an In-Hospital COVID-19 Vaccination Centre for Healthcare Workers

The doctoral candidate (A.Z.) is the first and corresponding author of this paper. A.Z. was responsible for conceptualising the project and data analysis plan for the manuscript with supervision from K.A. and consultations with S.K. and S.H. That includes the design of the data collection tool (survey) as described above.

A.Z. was responsible for planning and executing the statistical analysis as well as for interpreting the outcomes from the two surveys presented in this paper. All other data concerning the vaccination centre was collected and analysed by S.H. Further, A.Z. was

responsible for curating and visualising the data from the survey and supported the interpretation and visualisation of the data from the program monitoring of the in-hospital vaccination centre. A.Z. wrote the original draft, collected, and incorporated input from all co-authors, where S.H. provided the text passages and data concerning to the vaccination centre and its operational management.

A.Z. coordinated the submission process of the manuscript including the integration of and the responses to the reviewers' comments. All co-authors provided integral input at all stages of the manuscript preparation including the review and editing of the publication draft.

2. Introduction

2.1 Background – Vaccine hesitancy as a public health challenge

Among the wide variety of public health preventive measures against the spread of infectious diseases, vaccines have thus far demonstrated to be a particularly effective and efficient method applicable in diverse contexts [2]. Evidence on this statement extends to the COVID-19 pandemic as well, as modelling data demonstrates that just within the first year of vaccine provision approximately 14.4 million deaths from COVID-19 had been prevented worldwide as a direct result of the unprecedented vaccine effort [3].

The World Health Organization (WHO) had thus set a goal of achieving a global COVID-19 vaccination rate of 70% by the middle of the year 2021 [4]. As this mark has been missed, an exhaustive analysis of the reasons behind this development could help facilitate the design of future vaccination efforts.

Among the reasons for the suboptimal COVID-19 vaccination coverage present in societal discourses worldwide, inadequate vaccine uptake due to a lack of willingness for receiving an inoculation has been a particularly prominent factor [5-8]. This issue presents an eminent challenge in the general prevention of infection diseases, especially following the introduction of pharmacological interventions, and refers to the concept of **vaccine hesitancy**, defined as the “delay in acceptance or refusal of vaccines despite availability of vaccine services” [9,10]. Although the term emphasises a rather negative connotation of vaccine rejection, it is crucial to clarify and accentuate the intricacy, gradation, and context-dependency of the concept [11].

The complexity of the topic is particularly reflected in the presence of vaccine-hesitant attitudes among healthcare workers (HCWs). This issue has been observed in the context of established vaccines, i.e. the seasonal influenza vaccination, as well as in regard to newly approved vaccines, i.e. against pH1N1 during the pandemic of 2009 [12-21]. However, the interest in observed vaccine hesitancy among HCWs exceeds the concern regarding the vaccine coverage in the cohort as a fragment of the general population in several manners. Firstly, HCW’s vaccine-related decisions and the beliefs and opinions these are based on, may significantly affect their willingness to recommend the respective vaccine to other people and especially patients [22]. Furthermore, HCWs are considered to be among the most trusted sources of information on healthcare topics including vaccinations, leading to their role as experts and gatekeepers both in bilateral exchanges, i.e. within the patient-provider relationship, as well as in the context of mass communication, e.g. when providing their professional opinion in a journalistic interview setting [23-28]. This additionally presents a challenge for the coherent framing of information within the scope of vaccine uptake promoting campaigns [29]. Moreover, from a rather inward and pragmatic perspective, vaccine hesitancy among HCWs impedes the prevention of nosocomial exposure to infectious diseases among HCWs themselves, as

previously published data shows a correlation between lower or absent vaccine uptake (prior to the authorisation of any COVID-19 vaccine) and a higher incidence of nosocomial COVID-19 outbreaks [30,31]. Considering all aspects of vaccine hesitancy in the context of HCWs and the COVID-19 pandemic, the issue requires a comprehensive analysis.

An additional specific aspect is depicted by the complexity of pandemic measures implemented on national, regional, local level as well as within the LMU University Hospital, as the full scope of these spreads across a wide spectrum of non-pharmaceutical measures (NPIs), e.g. mask mandates, regular testing, travel restrictions, as these may further affect the intent to vaccinate [32].

This postulates the first research question of this thesis: **what is the general attitude of HCWs towards COVID-19 vaccines and which factors affect the decision-making process towards accepting, refusing or being ambivalent towards receiving an inoculation? Additionally, recognizing the complexity of topic, we examine the attitude towards NPIs following a COVID-19 vaccination and how the intent of receiving a vaccine may affect one's position regarding other preventive measures.**

This topic of interest and especially the latter aspect of the first research question is further expanded and complemented by novelty of the COVID-19 prevention measures catalogue implemented at the LMU University Hospital and the significance of their evaluation [33]. This refers especially the assessment of the vaccination centre designed for the COVID-19 in-hospital vaccination campaign as it presented a unique approach for the LMU University hospital and a sharp diversion from the established practices at the hospital. Thus, the second aspect of this thesis refers to the research question on the evaluation of the in-hospital vaccination center implemented at the LMU University Hospital: **how did the employees vaccinated at the in-hospital center describe their vaccination experience and their satisfaction with the process and the center? Which factors may affect the satisfaction with the COVID-19 vaccination and vaccination process? Further, we examine how the staff members of the center perceived the work setting as well as the organization of the whole vaccination process.**

The research questions of this thesis were presented in two papers in peer-reviewed journals. In the following chapters, the topic will be expanded beyond the presentation of the results published in the two papers by offering a broader context to the outcomes of the research articles and their potential expansion across interdisciplinary theoretical and empirical contexts. Additionally, this thesis will outline evidence-informed recommendations for the design of vaccination campaigns in similar settings derived from the outcomes of the published analyses and their integration into analytical and practical discourses.

2.2 Methods

Data collection

Data was collected within the frames and of the project IMPF^{LMU} described above. Online-based cross-sectional anonymous surveys were the preferred choice of data collection method in order to allow for a high comparability of the results with previously published studies on the same and similar research topics conducted in analogous populations and settings [1,34-40].

Overall, we conducted three surveys. **Survey 1 aimed to assess the willingness to receive a COVID-19 vaccination.** As the motivation for vaccination and health behaviour uptake can be framed by personal as well as environmental factors, this survey attempted to identify the relevant associated factors and possibly create an explanatory framework of how these affect the decision-making process in terms of COVID-19 vaccination. Further, this survey aimed to determine the information and communication needs of HCWs in order to, subsequently, outline practical recommendations for the design of vaccination promotion campaigns in similar settings.

Surveys 2 and 3 aimed at evaluating the vaccination process at LMU University Hospital. Survey 2 attempted to gather data on the satisfaction of HCWs that have been vaccinated at the in-hospital centre with the vaccination process (henceforth called "vaccinees"). Beyond surveying the satisfaction with the vaccination process including organisation, information on vaccination and safety, this survey further collected data on the observed self-reported adverse effects following immunization (AEFIs). Lastly, Survey 3 explored the satisfaction of the vaccination center staff with the organization of the center including workload.

All surveys were conducted using between February 25 and June 30, 2021 LimeSurvey Version 4.4.12+210308 (Survey 1 time frame: February 25 – March 20, 2021; Surveys 2 and 3 time frame: April 14 – June 30, 2021).

Population and definition of HCWs

All surveys were conducted at the LMU University Hospital (N=11,070) [41]. The LMU University Hospital is a maximum care facility fulfilling a triple mandate, where the operational domains of patient care, research and teaching are closely intertwined [41]. Due to the broad spectrum of functions and responsibilities of the facility, for the purpose of the IMPF^{LMU} project as well as for this dissertation, HCWs are defined as "all persons employed by a healthcare facility and providing care or services enabling the functioning of the health facility and the fulfilment of its mandate".

This definition goes beyond the concept of "health professionals" as defined by the International Labour Organisation due to the following arguments [42]: firstly, the vaccination campaign evaluated with the presented project was aimed (in its full extent) to all persons employed directly or indirectly, with or without pay (e.g. interns) or volunteering at the LMU University Hospital; moreover, all persons working at the facilities of a hospital have an overall higher exposure to COVID-19 compared to the general population

[30]; further, all persons working at the LMU University Hospital contribute to the functioning of the whole facility and enable the fulfilment of its mandate in healthcare provision, teaching and research; lastly, all persons working at the LMU University hospital were covered by the later adopted COVID-19 vaccination mandate for healthcare workers in Germany [43].

The broad formulation of the cohort definition serves as an advantage of this examination as it encompasses the full spectrum of employees at a university hospital and yet, may be considered a limitation as most of the literature on the topic only focuses on persons executing a health profession, similar to the definition of the International Labour Organisation.

Theoretical framework

The methods of this project as well as of both publications are laid upon a broad theoretical basis. For the design of surveys 1 and 2, the Health Belief Model (HBM) was applied as a guiding framework in order to account for wide range of contextual factors potentially associated with the decision-making process resulting in the uptake, refusal or indecisiveness regarding a health promoting measure in general [44,45]. HBM is among the most widely used concepts in the examination of individuals' behaviour and attitudes towards health prevention and promotion activities [46,47].

Additionally, questions from the survey tool developed by the WHO SAGE Working Group in Vaccine Hesitancy were incorporated in the surveys 1 and 2 as to collect data on vaccine-specific issues, which may affect the intent for receiving a COVID-19 vaccine specifically [48]. Lastly, the design of surveys 1 and 2 was completed by elements specific to the evaluation needs of the LMU University Hospital. The design of survey 3 was solely based on the evaluation needs of the LMU University Hospital and the management of the vaccination centre.

This combination of established theoretical foundations and needs-based aspects allowed for the questionnaires to be developed as holistic tools for exhaustive yet targeted data collection.

2.3 Paper I – Factors associated with the COVID-19 vaccination intent and status among HCWs

Several studies have explored the intent of HCWs to get vaccinated against COVID-19 prior to the authorisation or distribution of any of the currently available vaccines. With the rate of willingness to vaccinate extending along of the range of 27% to 76%, the available data were indicating significant levels of uncertainty both among the studied cohorts as well as in regard to the validity of data, especially considering the aim to report data on the willingness to receive an yet unknown immunisation at the time of data collection [35-40,49-51]. Beyond the motivation for further exploration of the issue of vac-

cination intent indicated from the results of the ACC study, the research questions explored in the first publication of this thesis were largely based on the interest in identifying the exact factors influencing the decision regarding a COVID-19 vaccine.

In accordance with other studies among HCWs conducted prior to any COVID-19 vaccine authorisation, the results presented in the first publication showcase a shift in vaccine attitudes towards higher acceptance and uptake [1,8,51-54]. The survey results analysed in this part of the project provided insights into the two individual groups of the cohort that were undecided or strictly reluctant towards receiving a COVID-19 vaccination. As presented in the publication in detail, several factors were observed to be associated with the respective decision on intending, refusing or being undecided towards a COVID-19 vaccine. The data highlighted the significant associations between HBM constructs and the willingness for receiving a COVID-19 inoculation with perceived benefits and barriers presenting particularly strong results, while comparatively low or unchanged over the time perceived susceptibility and severity regarding COVID-19 were also associated with a tendency towards refusing or being undecided on receiving an inoculation [38,40,55-58]. Furthermore, the results support previously published evidence on the association between not having received an influenza vaccine in the previous influenza vaccination campaign with indecisiveness or refusal of a COVID-19 vaccine, while an association between a general attitude towards vaccines and any of the available COVID-19 vaccines remains currently unexplored within the frameworks of the measurement tools utilised here [49,50,55,59-61]. It should be noted, that in order to provide a deeper understanding of the factors influencing the decision-making process in terms of COVID-19 vaccination, the analyses were executed using the individual items of the HBM constructs as well utilising individual aspects of the WHO SAGE survey tool. This was of particular interest with reference to potential extrinsic measures that could be or could have been adopted in order to facilitate vaccination uptake, such as dissemination activities by the employer (in this case, the LMU University Hospital). Thus, in the context of this publication and this thesis there is a particular aim to identify potential areas for targeted impact, specifically in terms of communication.

Hence, the communication and information aspects of this first publication present a distinct focus of analysis and discussion in the form of the explored cues to action. Several essential outcomes call for a particular deliberation as these provide the outline for the best practice recommendations compiled later on in this thesis.

Media and information consumption

The observed association between COVID-19 vaccine refusal and not consuming information provided through public channels or by official stakeholders (e.g. health authorities) contribute data to the reported high frequency of mistrust towards the respective actors and channels [55]. As trust, or the lack thereof, in official health authorities as well as the consumption of mass communication (“traditional”) media are positively linked to, respectively, vaccine acceptance or hesitancy, this aspect of the reported results calls for a recommendation towards quantifying and optimising the trust of HCWs towards

vaccine information providers [16,62-67]. This recommendation would consider as outcome not only the vaccination rates among HCWs themselves but would also have a noticeable effect on vaccination uptake in the general population, as HCWs' trust in official sources significantly affects their willingness and frequency of recommending the respective vaccines to patients [63].

Considering the topic on a rather institutional level or within the frames of a single organisation, our results reflect the findings published from similar studies in regard to the attitudes of one's peers and colleagues actively influencing one's decision-making process [55]. This refers both to personal contacts within the private circle as well as professional contacts on the same or on different organisational levels [56].

It should, however, be noted that the data collection for both papers preceded the adoptions of the COVID-19 vaccination mandate in healthcare facilities in Germany. This is particularly relevant to the analysis of factors associated with the willingness to receive a vaccine and serves both as a limitation as well as an advantage of this publication: where a mandate could potentially increase the acceptance and uptake of a vaccine [52-54,68-72], evidence suggest that a HCWs income, their occupational group or their own intent to get vaccinated may influence their recognition of a vaccination mandate as a useful public health measure [34,73,74]. Vice versa, a vaccination mandate may also impede the willingness to vaccinate [37,58,74,75].

However, the timing of data collection provided the opportunity to discriminate between already and not yet vaccinated participants with an intent to do so. Thus, we examined possible associations between a positive vaccination status and factors that might be linked to it. Notably, we observed a positive association between having already received at least one COVID-19 vaccination and approving the extension of the validity of non-pharmaceutical interventions (NPIs) at the workplace [55]. This result provides an empirical indication for the potential mutual association between one's attitude towards pharmaceutical and non-pharmaceutical measures, hence underlining the complexity of the vaccination decision-making processes in individuals and the scope of the topic surpassing the limits of a single and uniform decision for or against an inoculation.

2.4 Paper II – Evaluation of the vaccination experience and associated factors

The theoretically and empirically observed association between past vaccination experiences and a willingness to vaccinate in the future posed the research question aiming to explore the perception of HCWs of their COVID-19 vaccination experience [48]. This led to the evaluation of the in-hospital vaccination centre at the LMU University Hospital with a particular focus on the satisfaction of HCWs that have received at least one vaccination in the centre (hereafter referred to as '*vaccinees*'). Specifically, we observed that vaccinees that perceived the centre as comparably less accessible (geographically and time-wise) as well as those who reported an increased frequency of AEFIs compared to

others, were less satisfied with their vaccination experience than vaccinees with comparatively fewer self-reported AEFIs and accessibility issues [76]. Particularly this result serves to accentuate the conjunction between the individual aims of this project, respectively the individual research questions of the two published articles, to an emphasised common theme extending beyond the scope of the analyses presented here: namely, the interplay between vaccination intent and the satisfaction with a vaccination experience.

Experiencing AEFIs following a COVID-19 vaccination has been positively associated with a reduced intent for receiving additional vaccinations, i.e. booster or annual vaccines, among HCWs [53,77,78]. As stated above, a HCWs own intention or willingness to vaccinate may significantly, directly or indirectly, affect the respective vaccination coverage in the general population [23-28]. One specific limitation of the analyses presented in this part of the project refers to the lacking data collection in terms of future willingness for receiving a follow-up COVID-19 vaccination. However, during the period of survey question design and compilation (December 2020-February 2021), there were no regulations nor recommendations for inoculation beyond the basic immunisation.

Another distinct issue of the results presented in this second publication refers to the possibility of reported AEFIs and especially their intensity to have been potentially affected by other persons reporting AEFIs, including reports in mass and social media but also personal observations or reports of persons experiencing AEFIs. This effect, based on the concept of agenda setting and the often intertwined with it concept of priming, ascribes to the notion that people's attitudes are directly affected by accessible and saliently presented information [79]. As similar observations have also been made in the context of COVID-19 information but also more specifically regarding COVID-19 vaccines, a certain degree of influence and bias in the individual's perception of AEFIs cannot be excluded [79-82]. Considering the theoretical perspective of this interpretation, as agenda setting and priming are memory-based models of information processing, any effects observed in this aspect do theoretically fall into the category of Historical influences (under "Contextual influences") identified by the SAGE Working Group on Vaccine Hesitancy as a relevant associated factor [48,79]. This analytical link again highlights the likelihood of the negative association between one's satisfaction with the vaccination process at LMU University Hospital as well as one's reports of AEFIs and their future willingness to receive another COVID-19 vaccine. A comparable link has been observed in a recent study showcasing AEFIs experience being associated with a decreased intent to receive regular COVID-19 booster inoculations in the future [78]. Indeed, in the particular case of HCWs working with patients, this effect has been observed in an extended context where observing AEFIs in patients was reported to have increased the likelihood of vaccine hesitancy in oneself and is supported by evidence for increased pain perception following noxious verbal or non-verbal priming [83-86]. As this aspect of AEFIs perception was not explored in the project described here but addresses a potentially relevant factor in the perception of AEFIs by HCWs and their subsequent decision-making

process in terms of future inoculations, this research questions represents a valuable area for prospective analyses.

Observed prospectively and from the perspective of technological and communication-based recommendations, Gianfredi et al. present theoretical and empirical data for the advantages of systematic monitoring and report of AEFIs for the trust-building process in the respective vaccine but also in the corresponding health authorities [87]. The specific implications of this evidence are outlined in chapter 2.3.1 under the subchapter “2. Capacity building for addressing vaccine hesitancy”.

Completing the investigation of the vaccination centre and process at LMU University Hospital and observing the context in which the vaccinees had made their experience, a short survey presented insights into the perceptions of the centre’s staff of the overall organisation. While the staff reported high levels of satisfaction, the perceived workload at the centre was neither lower nor higher than the workload at the staff’s regular positions [76].

2.5 General limitations of this project

There are several limitations to this project that need to be taken into consideration when interpreting the results and their potential impact.

In terms of design, this project only explored the effects of individual elements of the HBM constructs on COVID-19 vaccination intent but did not explore the sets of items as a whole. This, however, provides a deeper insight into the single aspects of the HBM constructs and how these affect the vaccination decision directly. Further, the project did not explore any potential association or modifying effects in-between the items or the single HBM constructs. This was mainly due to the theoretical and empirical inconsistency in terms of the associations in-between the constructs [45,88,89].

A further note on the design of the project concerns the lack of a segment of sociodemographic factors that would have been expected to provide a more detailed insight into the cohort. This regards the question of national, cultural, religious, and ethnic background as these factors are reported to be of significant relevance towards vaccination intention among the general population and HCWs [60,67,72,90-94]. No questions on the ethnical or national background of survey participants were asked in order to prevent any potential identification of the individual participants. This was a particular privacy concern as the project was supported by the employer of the targeted cohort. The same consideration applies to the questions of political orientation, political beliefs, and their potential effect on vaccination intent [72,90,95-97].

An additional consideration in terms of the timing of data collection concerns the availability of vaccines. The period of data collection for the first publication falls within the time period in which COVID-19 vaccine scarcity had being gradually decreasing, however still affecting the vaccination coverage, especially through the mechanism of vaccination pri-

oritisation of high-risk groups including HCWs [98]. As vaccine scarcity may affect vaccine acceptance, a certain modifying factor of COVID-19 vaccination availability and, especially, the vaccination prioritisation cannot be excluded [68,99].

In terms of reporting on the methods, although we examined the modifying effects of sociodemographic factors on the primary outcomes, the models including those as variables showed slightly limited model fits compared to the models excluding those, thus were not included in the main body of the publications but rather in their supplements. A specific report focused on the adjusted models rather than on the unadjusted models would have provided the identic outcomes, however with marginally different effect sizes.

2.6 Contribution of this thesis - Lessons learned, recommendations and best practices

Although the immediate impacts of the COVID-19 pandemic have been recently scaling down and the COVID-19 public health emergency of international concern has been declared ended, the issues that it accentuated and created in terms of vaccine acceptance and coverage remain a topic of concern on a global scale. COVID-19 vaccination uptake remains a critical topic for several reasons [100]. Firstly, following the mass introduction of vaccines, the incidence and prevalence of SARS-CoV-2 infections has been primarily driven by unvaccinated or not fully vaccinated persons [30,31,101,102]. Furthermore, SARS-CoV-2 antibodies have been shown to wane after approximately several months following the latest vaccination with age being a significant factor in antibody level decrease [103-105]. Additionally, persons of older age or with certain chronic diseases are considered to be more vulnerable towards becoming ill, developing severe symptoms following a SARS-CoV-2 infection and eventually requiring hospitalisation due to their higher risk of lower seroconversion and seroprotective rates compared to healthy individuals [106-109]. This factor highlights the necessity for additional COVID-19 vaccination over a regular period of time, i.e. booster shots. The latter aspect is further exacerbated by the relaxation or complete removal of NPIs, which consequently eliminates a critical set of prevention measures that had previously proven highly effective in averting or reducing the spread of SARS-CoV-2 [110-113]. A further aspect refers to the emergence of new variants as well as a hypothesized but not yet established seasonality of SARS-CoV-2 circulation [109,113,114]. Lastly, the outcomes of COVID-19-specific research, such as the analyses presented here, may be applicable to a broader set of research questions beyond the scope of the COVID-19 pandemic, as it will be discussed further in this chapter.

2.6.1 Contributions to occupational health promotion and management

The outcomes of this project serve as reference points for the design and layout of future large-scale vaccination campaigns in similar settings, i.e. hospitals. Similar to previously published research, this thesis highlights the need for a holistic approach to the topic rather than the implementation of single measures [13]. Specifically, the implications of

the outcomes presented within this thesis can be classified under the three categories of recommendations issued by the SAGE Working Group on Vaccine Hesitancy [115]. These are presented below.

1. *Facilitating the understanding and disseminating of vaccine hesitancy*

While HCWs represent only a very specific fraction of the general population, their eminent significance as experts and gatekeepers compels to exploring the specific reasons for vaccine hesitancy and reluctance among the subgroups. The individually analysed items of HBM constructs provide a deep understanding of the factors influencing the decision-making process, where the perceived benefits and barriers showed very strong associations [55]. Considering especially the strong association for concern regarding effectiveness and adverse events, the results presented here contribute to the growing body of literature observing that these concerns are equally present both in the general population as well as among highly specialised subgroups such as HCWs [16-19,52-54,56,78,116-119].

2. *Capacity building for addressing vaccine hesitancy*

Following the advanced understanding of the vaccination attitudes among HCWs, targeted communication strategies are urgently recommended. This is particularly relevant against the background of trust or lack thereof in health authorities and HCWs serving as information gatekeepers with significant potential for affecting the vaccination uptake among the general population [22-28,90,120].

Our results regarding the cues to action and especially on the communication needs and media usage of HCWs align with the evidence for the benefits of and, consequently, recommendations for the implementation of **interpersonal communication** measures when addressing vaccine hesitancy in a clinical setting [56,73,121]. Particularly the fostering of vaccine-related and vaccine-specific exchange on an individual or even team level can help enable valuable feedback loops that can serve as a tool within the frames of the concept of “social listening” – an infodemic management concept describing activities aimed to diagnose and understand concerns regarding vaccines and, subsequently, derive recommendations for measures targeting the identified issues [122-124]. Beyond identifying immediate concerns and topics in need to be addressed, social listening may significantly contribute to diagnosing gaps in an individual’s or team’s health and vaccine literacy that may also subsequently be managed through interpersonal and peer communication, as our results have highlighted its potential effect on one’s vaccine decision [125]. This refers especially to nonmedical professionals working in the multilevel interdisciplinary compound of a university hospital [126].

In terms of communication methods that may be applied in this context, tools developed for applications of the inoculation theory, such as prebunking (pre-exposure correction of potential mis- or disinformation) and debunking (post-exposure correction of mis- or disinformation), are particularly adaptable to both belief-consistent and memory-based information processing [127-130]. Communication measures in this context and with the respective tools may significantly affect, respectively, one’s belief-based foundation of

vaccine refusal or indecisiveness (as in the HBM-based discourse) as well as their memory-based information processing as discussed above in the framework of agenda-setting and priming.

3. Sharing best practices

Our outcomes provide a reference for future research and for the compilation of specific recommendations for the design of vaccination campaigns and the layout of large-scale vaccination centres in a hospital setting. By publishing the outcomes of this project, we are providing primary points for discussion and further research. In particular, the findings on the targeted need of communication, the organisation of the vaccination experience and particularly the occurrence and perception of AEFIs all present factors that may significantly affect the future intent of receiving COVID-19 vaccines even among population groups with generally high vaccine acceptance, such as HCWs.

The contributions of this thesis presented in this chapter additionally reflect the implications on the public health policies for COVID-19 vaccination roll-out campaigns by the European Centre for Disease Prevention and Control (ECDC) as they specifically address the determinants and factors of vaccine uptake and provide guidance for the design of targeted messaging especially among the high-priority group of HCWs [131].

2.6.2 Contributions to theoretical research

The project presented in this thesis may serve as reference to the theoretical constructs it is based on. Considering the specific to vaccine hesitancy approach of the SAGE Working Group and the survey tool that helped inform the questionnaires for this project, the results presented here emphasise the relevance of contextual factors and especially individuals' historical references [48]. The second publication of this project underlines several aspects of the SAGE questionnaire and especially the association between negative experiences resulting from an inoculation (i.e. AEFIs) and one's overall perception of the vaccination process. Considering that previous experiences may influence one's willingness to vaccinate in the future, this result can be interpreted as a call to action for improving, where possible, the overall experiences of vaccinees before, during and after the respective inoculation. This potential new research question can also be considered as to have been implied by the observed positive association between a generally approving attitude of vaccines and the intention to receive a COVID-19 inoculation [55]. This particular topic may pose a compelling issue in the discourse of the principle of aggregation and situational specificity of human behaviour discussed in the Theory of Planned Behaviour [132,133]. In this regard, bringing both articles and aspects of this project together as well as per the results of a recent comparable study from Israel, a new possible question for future research emerges in the exploring the complex association between vaccination intent prior to inoculation and the intent to receive a follow-up or regular booster vaccination with AEFIs experience serving as a modifying or confounding variable [78].

Observing the topic beyond the focus of vaccines and regarding the general implications for willingness to engage in preventive and health promotion behaviours, the HBM provided a fundament for exploring potential non-vaccination associated factors. The HBM is considered as a valuable theoretical framework for the design of health promotion communication campaigns [134]. The first publication of this thesis contributes to the growing body of empirical evidence where HBM is applied to operationalise and systematically collect data on vaccine hesitancy regarding and beyond COVID-19.

A recent systematic review exploring the appropriateness of HBM constructs in predicting primary and follow-up COVID-19 vaccination intent, which included the first publication of this project as well, observes significant associations between the individual constructs and one's intention to receive an inoculation [135]. Particularly, the results of the meta-analysis underscore the findings of this project in terms of the convincing association between vaccination intent and the HBM constructs of perceived benefits, barriers, and cues to action [135]. Although the results may fluctuate in-between countries and due to a variety of sociodemographic factors, HBM convinces as a suitable framework for exploring factors affecting the outcomes of a vaccine-related decision-making outcome. Surpassing the theoretical and empirical evidence of HBM and allowing for a short interdisciplinary theoretical excurse, the growing TPB-based evidence for the direct predictability of COVID-19 vaccination intent through the personal attitude towards vaccination as well as the recently proposed parsimony framework in bias research further accentuate the approach of belief-consistent information processing towards explaining the adoption of health promoting measures [90,136,137].

Nonetheless, the interpretation and potential impact of COVID-19 research results, such as those presented here, do not necessarily need to be confined to the context of COVID-19 itself or related infectious or other emergencies of international concern. As Hook and Wilsdon establish, the global surge of publications along the multifaceted spectrum of the COVID-19 pandemic appears to have rather strengthened and highlighted already pre-existing research and knowledge structures and networks, instead of creating fundamentally novel aspects and components in the scientific landscape [112]. Thus, the applicability and generalisability of COVID-19 research results could and should be observed beyond the idiosyncrasy and topical constraint of this pandemic, as the results presented in this thesis also display considerable significant historical and interdisciplinary references to social and communication sciences.

3. Summary

The presented analyses within the frames of this thesis provide detailed evidence into the arguments and background of the decision-making process of HCWs towards accepting, refusing or delaying a COVID-19 vaccine. While the perceived benefits of receiving an inoculation as well as the as low perceived barriers to the measure were positively associated with vaccination intent, comparatively lower perception of COVID-19 susceptibility and severity were linked to undecidedness or negation of a vaccine. Specifically, the analyses on the cues to action demonstrated how a feeling of being ill-informed on the topic of COVID-19 vaccines and their safety was associated with refusing or being undecided on an inoculation, where this perception was directly linked to low information consumption from official sources and low levels of interaction with other HCWs, while the targeted consumption of vaccine-specific information facilitated vaccine uptake. Beyond the immediate scope of COVID-19, factors positively linked to vaccination intent where a generally approving attitude towards vaccines as well as having been vaccinated against influenza in the past season. The observation of the association between the acceptance of pharmaceutical and non-pharmaceutical measures revealed that COVID-19 vaccine acceptance is associated with an approving attitude towards non-pharmaceutical interventions. These results provide detailed evidence for the reasoning, attitude, and behaviour towards a COVID-19 vaccine as a preventive measure.

Considering the memory-based information processing in vaccine-related decision-making and its potential impact on future COVID-19 or non-COVID-19-related inoculations, the further analyses presented here demonstrate a positive association between perceived inaccessibility of the vaccination centre, self-reported AEFIs and comparatively lower satisfaction with the process. Taken together, these outcomes outline a strategic framework for empirical recommendations on the occupational health promotion in health facilities with a focus on targeted communication using tools and measures from the field of infodemic management. Furthermore, the observed associations pose a theoretical and empirical inquiry into the interrelated juxtaposition between self-reported unsatisfactory vaccine-related experiences and future vaccine-related decision-making processes, where this research question may also be examined beyond the immediate context of the COVID-19 pandemic.

4. Zusammenfassung

Die im Rahmen dieser Arbeit vorgestellten Analysen liefern detaillierte Erkenntnisse über die Argumente und Hintergründe des Entscheidungsprozesses von Angestellten im Gesundheitswesen zur Annahme, Ablehnung oder Verzögerung einer COVID-19-Impfung. Während des wahrgenommenen Nutzens einer Impfung sowie die als gering wahrgenommenen Barrieren der Maßnahme positiv mit der Impfabsicht assoziiert waren, stand eine vergleichsweise geringere Wahrnehmung der COVID-19-Anfälligkeit und des Schweregrades in Zusammenhang mit der Unentschlossenheit oder Ablehnung einer Impfung. Insbesondere die Analysen zu den Handlungsaufforderungen zeigten, dass das Gefühl, schlecht über COVID-19-Impfstoffe und deren Sicherheit informiert zu sein, mit der Ablehnung oder Unentschlossenheit gegenüber einer Impfung verbunden war, wobei diese Wahrnehmung direkt mit einem geringen Informationskonsum aus offiziellen Quellen und einem geringen Maß an Interaktion mit anderen medizinischen Fachkräften zusammenhing, während der gezielte Konsum von impfstoffspezifischen Informationen die Impfstoffaufnahme förderte. Außerhalb des unmittelbaren Anwendungsbereichs von COVID-19 standen Faktoren wie eine allgemein zustimmende Haltung gegenüber Impfstoffen sowie die Tatsache, in der vergangenen Saison gegen Influenza geimpft worden zu sein, in einem positiven Zusammenhang mit der Impfabsicht. Die Beobachtung des Zusammenhangs zwischen der Akzeptanz pharmazeutischer und nicht-pharmazeutischer Maßnahmen ergab, dass die Akzeptanz von COVID-19-Impfstoffen mit einer zustimmenden Haltung gegenüber nicht-pharmazeutischen Interventionen verbunden ist. Diese Ergebnisse liefern detaillierte Belege für die Argumentation, die Einstellung und das Verhalten gegenüber einer COVID-19-Inokulation als Präventionsmaßnahme.

In Anbetracht der gedächtnisbasierten Informationsverarbeitung bei impfbezogenen Entscheidungen und ihrer potenziellen Auswirkungen auf künftige COVID-19- oder nicht-COVID-19-bezogene Impfungen zeigen die hier vorgestellten weiteren Analysen einen positiven Zusammenhang zwischen der wahrgenommenen Unerreichbarkeit des Impfzentrums, selbstberichteten Nebenwirkungen und einer vergleichsweise geringeren Zufriedenheit mit dem Impfprozess.

Zusammengenommen skizzieren diese Ergebnisse einen strategischen Rahmen für empirische Empfehlungen zur betrieblichen Gesundheitsförderung in Gesundheitseinrichtungen mit dem Fokus auf gezielte Kommunikation unter Verwendung von Instrumenten und Maßnahmen aus dem Bereich des Infodemie-Managements. Darüber hinaus stellen die beobachteten Assoziationen eine theoretische und empirische Untersuchung des Zusammenhangs zwischen selbstberichteten unbefriedigenden Impferfahrungen und –nebenwirkungen und zukünftigen impfbezogenen Entscheidungsprozessen dar, wobei diese Forschungsfrage auch über den unmittelbaren Kontext der COVID-19-Pandemie hinaus untersucht werden kann.

5. Paper I

Zhelyazkova, A.; Kim, S.; Klein, M.; Prueckner, S.; Horster, S.; Kressirer, P.; Chouker, A.; Coenen, M.; Adorjan, K. COVID-19 Vaccination Intent, Barriers and Facilitators in Healthcare Workers: Insights from a Cross-Sectional Study on 2500 Employees at LMU University Hospital in Munich, Germany. Vaccines (Basel) 2022, 10, doi:10.3390/vac-cines10081231.

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Abstract: Considering the role of healthcare workers (HCW) in promoting vaccine uptake and previously recorded hesitancy among HCW, we aim to examine the COVID-19 vaccination intent and status of HCW through a cross-sectional anonymous online survey at LMU University Hospital in Munich. Data collection was informed by the Health Belief Model (HBM) and focused on vaccination intent, status and on potential factors affecting the decision-making process. In total, 2555 employees completed the questionnaire. Our data showed that an approving attitude towards recommended vaccines and having received an influenza vaccine in the previous winter were strongly associated with COVID-19 vaccination intent. Further, a positive COVID-19 vaccination status was associated with a higher likelihood of approving the extension of the validity of non-pharmaceutical interventions at the workplace. Our HBM-analysis demonstrated strong associations between the perceived benefits and barriers and COVID-19 vaccination intent. Unchanged or low perceived susceptibility and severity were associated with refusal or indecisiveness. Our findings highlight the factors associated with the decision regarding a COVID-19 vaccine and indicate a pattern-like behavior in the acceptance of novel vaccines by HCW. These insights can help inform the communication aims of vaccination campaigns among HCW within similar organizational contexts or in future outbreaks.

Keywords: COVID-19; vaccination; vaccination hesitancy; healthcare workers; health belief model; vaccination; non-pharmaceutical interventions

1. Introduction

One of the top priorities in the World Health Organization's strategic pandemic management has been defined as achieving a global COVID-19 vaccination coverage by the middle of 2022 [1]. In order to achieve this milestone, healthcare workers (HCW) take on a

particularly important role due to their high risk of contracting and spreading an infectious disease in a nosocomial context as well as due to their essential function in healthcare services provision [2]. Furthermore, HCW are considered to be gatekeepers and trusted sources of information regarding vaccination among their patients as well as the general population [3,4]. However, diverging attitudes and intentions regarding immunizations can be observed among HCW, as well [4,5].

During the 2009/2010 pandemic influenza (pH1N1) outbreak, unexpectedly low levels of pH1N1 vaccination were reported among HCW worldwide [6]. Although the spread of SARS-CoV-2 presents a different pandemic context, fluctuations in the intent of HCW to receive a COVID-19 vaccine can be observed. The "All Corona Care" study conducted in 2020 (May to July) at LMU University hospital, one of the largest in Germany, asked participants prior to the authorization of any COVID-19 vaccine if they would be willing to get vaccinated if there were an efficient vaccine available with few side effects. Out of 7554 participants in the study, 58.2% were willing to get vaccinated [7]. Still, it remained to be explored if and how the vaccination intent in this HCW cohort would shift after the authorization of the first COVID-19 vaccines as well as which factors and aspects drive the decision-making process towards accepting, delaying or refusing a vaccination.

This study aims to examine the COVID-19 vaccination intent and vaccination status of HCW at one of the largest hospitals in Germany and to identify factors associated with the COVID-19 vaccination intent and vaccination status. The methodological framework of this study rests upon the Health Belief Model (HBM) as one of the most established theoretical concepts in health behaviour research and a preferred concept in the examination of the individuals' acceptance and attitudes towards health promoting and disease preventing behaviours and measures [8,9]. The methods are further informed by the measurement recommendations of the SAGE Working Group on Vaccine Hesitancy in regard to vaccination intent [10,11].

Specifically, in this report, we aim to provide evidence on the topic by examining the following sets of hypotheses:

1. General attitude towards vaccines and COVID-19 vaccines;
2. Attitude towards other non-pharmaceutical interventions (NPIs) following a COVID-19 vaccination;
3. Factors associated with the intent to vaccinate (informed by the HBM).

2. Materials and Methods

We conducted a cross-sectional anonymous online survey targeted at all employees of LMU University Hospital in Munich between 25 February and 20 March 2021 to gather data regarding the intent to receive the COVID-19 vaccine as well as the factors associated with the decision. LimeSurvey Version 4.4.12+210308 was used for the design of the questionnaire.

The survey was conducted as part of a prospective study to evaluate the vaccination process at the LMU University Hospital in the course of the COVID-19 pandemic ($IMPF^{LMU}$). The study was reviewed and approved by the ethics committee of the medical faculty at LMU Munich, Germany (Project number: 21-0123).

With 11,070 employees and 101 departments, the LMU University Hospital is the second largest university hospital in Germany [12]. The vaccination campaign against COVID-19 began in 27 December 2020 and proceeded until 17 July 2021, thus being among the first hospitals in Germany that set up a vaccination centre and a large-scale vaccination campaign for their employees [13]. At the point of the launch of the survey, approx. one third of the hospital's employees had received at least one vaccine dose. The vaccination campaign was set up with several consecutive prioritisation phases, where hospital personnel with the highest COVID-19 infection risk were the first to receive a vaccination appointment (e.g., personnel of the emergency department, COVID-19 departments). Due to ministerial distribution algorithms, the LMU University hospital vaccination centre exclusively used the vaccine "Comirnaty" (BNT162b2) during this vaccination campaign,

however, employees were not deterred from attending an appointment at a different vaccination centre (e.g., communal centres). Hospital employees vaccinated at a different vaccination centre were also able to participate in the survey. For the purposes of this study, we define vaccine hesitancy as a delay in acceptance or refusal of vaccines despite availability of vaccine services [11].

The questionnaire was developed based on the in-house evaluation needs as well as on a literature review. The questions were categorized in six sections: (1) general media consumption (two questions), (2) in-house media consumption (three questions), (3) in-house media consumption regarding COVID-19 vaccinations (three questions), (4) general attitude towards vaccines (three questions), (5) general attitudes towards COVID-19 vaccines (eight questions) and (6) socio-demographic data (seven questions). The design and selection of questions for sections 1, 4 and 5 were informed by the previous work of the WHO Strategic Advisory Group of Experts (SAGE) as well as by the implementation of the HBM in predicting health behaviours [8–11,14]. Previous studies on the acceptance of COVID-19 and other vaccines have showcased the suitability of HBM for exploring this type of research questions [15–17].

The questionnaire was designed in German and translated into English for the purposes of this publication.

The primary outcome of the survey was the intent to receive a vaccination against COVID-19 (section 5). The main question gathering information regarding the intent to vaccinate was formulated as "Are you going to get vaccinated against COVID-19?" and provided four options to respond: "Yes", "No", "Maybe", and "I have already received one or both of the vaccination doses". The latter option was necessary as the vaccination campaign had begun approximately two months (28 December 2020) prior to the rollout of the survey (25 February 2021). Participants who had selected "Yes" or "I have already received one or both of the vaccination doses" were forwarded to a multiple-choice question about their reasons for wanting to receive a COVID-19 vaccine. Participants who had selected "No" were asked, through a multiple-choice question, about their reasons for denying a COVID-19 vaccine. Participants who had indicated indecisiveness ("Maybe") were presented with a multiple-choice question on the factors that could potentially serve as motivators for them to receive a COVID-19 vaccine.

Responses on the main question were used to build two variables: one indicating intent to vaccinate (containing the responses "Yes", "No" and "Maybe", excluding already vaccinated participants) and one indicating the vaccination status (dichotomous "vaccinated" and "not vaccinated"). The newly created variables were used for testing the presented hypotheses. Perceived susceptibility, severity, benefits and barriers were measured using a 5-point Likert scale. The Likert scale was subject to regrouping, since, for the majority of the items, the original scale did not provide a subgroup sample size large enough to execute the multinomial regression. Furthermore, the consistent regrouping of the 5-point Likert scale enhances the comparability of results.

Due to the absence of a universally agreed upon process-oriented methodology in HBM research, we opted for an individual examination of the associated constructs instead of parallel, serial or a moderated analysis [18]. Further, we executed the analyses in an itemized manner in order to provide insights into the specific aspects driving the association between HBM constructs and vaccination intent.

The survey (including information about the IMPF^{LMU} study) was disseminated through a designated intranet page as well as through the employee newsletter, available to all employees. Several reminders were sent between 25 February and 20 March 2021. All employees of the hospital were eligible to participate in the survey.

Statistical Analysis

Descriptive analysis was performed for the sociodemographic data as well as the data on internal communication, general communication (partially) and on the responses regarding the reasoning for the vaccination decision. Potential confounders and effect

modifiers (age, sex, occupational category, education and direct work with COVID-19 patients) were tested for significant associations with vaccination intent and status using a Pearson's Chi-square test (Table 1). Only significant variables were included in the following analyses ($\alpha = 0.05$).

All hypotheses were tested for both vaccination intent and status, where multinomial logistic regression models were used for vaccination intent (AIC, BIC) and binomial logistic regression models were applied to test the vaccination status (Cox and Snell R-Quadrat, Nagelkerkes R-Quadrat). The hypotheses on the HBM-based cues to action (H3) as well as on the attitude towards NPIs (H2) were examined with a multinomial logistic regression (AIC, BIC). One hypothesis on the utilization of media and perceived knowledgeability was tested with a generalized linear model (Pearson's Chi-square Test).

Due to the small subgroup size in some variables where the data were collected using a 5-point Likert scale, items on the lower end of the scale (coded "1" and "2") as well as items on the upper end of the scale (coded "4" and "5") were respectively collapsed, thus providing a variable with three response options.

Data processing and analyses were conducted with IBM SPSS Statistics Version 26.0.0.0. Depending on the model fit, the unadjusted models were preferred for interpretation. Unreported models are presented as tables in Supplement B.

3. Results

In total, 3590 of 11,070 employees (32.4%) of LMU University hospital participated in the survey. Of those, 2555 completed the questionnaire in full. Only fully completed questionnaires were considered for further analysis. Table 1 shows the frequency and distribution of the socio-demographic and occupational characteristics of participants as well as the distribution of vaccination status and intent among respondents. Table 2 provides insight into the reasons of participants for their vaccination decision. The data show that protecting oneself and one's close ones dominates arguments for receiving a COVID-19 vaccine, whereas uncertainty about the vaccines' effectiveness and safety were leading causes for refusal and uncertainty.

Table 1. Socio-demographic and occupational characteristics of participants.

	n	%	Coefficient *p*-Value	
Age *			**Intent to Vaccinate**	**Vaccination Status**
<29 years	487	19.1		
30–39 years	604	23.6		
40–59 years	523	20.5	0.130	0.081
50–69 years	683	26.7	0.000	0.005
>60 years	239	9.4		
No answer	19	0.7		
Sex **				
Female	1807	70.7	0.048	0.073
Male	739	28.9	0.193	0.001
Other	9	0.4		
Education				
Secondary/Elementary school	40	1.6		
Middle school	331	13.0		
High school/technical diploma	439	17.2		
Vocational training	497	19.5	0.106	0.203
Academic degree (Bachelor)	193	7.6	0.019	<0.001
Academic degree (Master/Diploma)	420	16.4		
Academic degree (Doctorate or higher)	574	22.5		
Other training	60	2.3		
No diploma	1	0.0		

Table 1. *Cont.*

	n	%	Coefficient *p*-Value	
Age *			**Intent to Vaccinate**	**Vaccination Status**
Occupation ***			0.036	–0.458
Medical staff	1478	48.7	0.426	<0.001
Non-medical staff	1120	51.3		
Work with COVID-19 patients				
Yes	446	17.5	0.051	0.257
Mean number of weeks **** = 19.27 (SD = 19.75, 1–60 weeks)			175	<0.001
No	2109	82.5		
Vaccination status				
Vaccinated	1235	48.3		
Not vaccinated	1320	51.7		
Intent to receive a COVID-19 vaccine (not vaccinated)				
Yes	1104	83.6		
No	82	6.2		
Maybe	134	10.2		
All (not vaccinated)	1320			
All	**2555**			

* Age group distribution at LMU University Hospital: <29 years = 22.9%, 30–39 years = 29.1%, 40–59 years = 18.8%, 50–69 years = 20.9%, >60 years = 8.4%. ** Sex distribution at LMU University Hospital: Female = 66.3%, Male = 33.7%. *** Occupational distribution at LMU University Hospital: Medical staff = 45.4%, non-medical staff = 54.6%. **** The question was only available to fill out by participants who had selected "yes" to having had worked at a designated COVID-19 unit or with COVID-19 patients.

Table 2. Frequencies of the reasons for the respective decision on COVID-19 vaccine.

What are your main reasons for willing to receive a COVID-19 vaccine? *	***n***	**%**
To protect others (family, colleagues, patients)	2210	94.5%
To protect myself	2171	92.8%
I want to contribute to maintaining public health and achieving collective immunity	1839	78.6%
I am worried for my family and relatives	1523	65.1%
To participate in social activities again (restaurant visits, concerts etc.)	1428	61.1%
So I can travel again	1370	58.6%
I am fully convinced of the effectiveness and safety of COVID-19 vaccines	1245	53.2%
To lead with example at the hospital	1047	44.8%
I am afraid of getting seriously ill from COVID-19	851	36.4%
I am afraid of getting infected with COVID-19	835	35.7%
I work with COVID-19 patients	662	28.3%
I am not fully convinced by the effectiveness and safety of COVID-19 vaccines but I see those as the lesser of two evils	496	21.2%
I identify as a risk patient	407	17.4%
Due to societal expectations	107	4.6%
As to not be identified as an "antivaxxer"	34	1.5%
I work with very vulnerable patients	10	0.4%
What are the reasons for which you do not (yet) wish to receive a COVID-19 vaccine? **	***n***	**%**
I am afraid of the long-term (yet unknown) reactions to the vaccines	69	87.3%
I am not convinced of the safety and effectiveness of COVID-19 vaccines	67	84.8%
I have concerns due to the fast-tracked process of development	62	78.5%
I am still lacking evidence on the effectiveness and safety of COVID-19 vaccines	53	67.1%
I am lacking trust in the mechanism of mRNA vaccines	49	62.0%
I am lacking trust in the health institutions, pharma companies or the media	40	50.6%
I do not belong to a vulnerable group	31	39.2%
I am afraid of short-term reactions to the vaccines	25	31.6%
I am not prepared to get vaccinated in order to protect others	21	26.6%
I have no contact with COVID-19 patients	21	26.6%
I think the restrictions regarding hygiene (e.g., mask mandate) are enough	21	26.6%
It is unlikely for me to get ill from COVID-19	19	24.1%

Table 2. *Cont.*

I generally do not get vaccinated	13	16.5%
I've already had COVID-19 and did not perceive it as so bad	7	8.9%
I've already had COVID-19 and am hence immune	4	5.1%
Due to health reasons (incl. pregnancy)	3	3.8%
Due to cultural or religious reasons	2	2.5%
I currently have no time for a vaccine	1	1.3%
What could positively influence your willingness to receive a COVID-19 vaccine? ***	***n***	**%**
More evidence on the long-term effects of COVID-19 vaccines	109	82.6%
More scientific evidence on the safety of COVID-19 vaccines	87	65.9%
More scientific evidence on the effectiveness of COVID-19 vaccines	85	64.4%
More time between the market authorization and myself receiving the vaccine—I prefer to wait a little longer.	74	56.1%
A longer process of vaccine development	61	46.2%
An exhaustive explanation about the different mechanisms of COVID-19 vaccines	52	39.4%
More general information about COVID-19 vaccines (e.g., in media)	41	31.1%
My family and friends getting vaccinated and going through the process well	36	27.3%
Personal conversations with an expert	33	25.0%
Personal conversations with already vaccinated colleagues	31	23.5%
High incidence and mortality rates in my area	18	13.6%
Participation in vaccine trials	17	12.9%
Delay due to health reasons incl. pregnancy	5	3.8%

* This was a filtered question available only to those who had replied with "yes" or "I have already received one or both of the vaccination doses" to the previous question ("Are you going to receive a COVID-19 vaccine?"); n = 2339. ** This was a filtered question available only to those who had replied with "no" to the previous question ("Are you going to receive a COVID-19 vaccine?"); n = 82. *** This was a filtered question available only to those who had replied with "maybe" to the previous question ("Are you going to receive a COVID-19 vaccine?"); n = 134.

For vaccination intent, age and education showed weak positive associations (Table 1). For vaccination status, all tested variables showed a weak positive association except for the dichotomous variable for occupation, which demonstrated a strong negative association (Table 1).

All variables with an association on vaccination intent or status were included in the adjusted multinomial and binomial logistic models, respectively.

3.1. General Attitude towards Vaccines and Influenza Vaccine Uptake

We examined the association between the general attitude towards vaccines and the COVID-19 vaccination intent (Table 3). The data show a strong association between capacity of an individual's opinion about generally receiving the recommended vaccinations and one's intent to get vaccinated against COVID-19. Respondents who do not or only partially agree with the statement that everyone should receive the recommended vaccines had a significantly higher probability of refusing a COVID-19 vaccine. Equivalently, respondents who do not or only partially agree with the statement had a significantly higher probability of being undecided on whether or not to get vaccinated.

In terms of dealing with negative comments (e.g., comments on ineffectiveness, harms) regarding vaccines in general as a predictor for COVID-19 vaccination intent, the data show only a limited effect. Regarding dealing with negative comments, people who do (often) deal with negative comments had a significantly higher probability of refusing a COVID-19 vaccine (Table 3).

The influenza vaccine uptake in the winter of 2020/2021 was associated with COVID-19 vaccination intent. The data in the better fitted unadjusted model show that people who were vaccinated against influenza at the end of 2020 or beginning of 2021 have a significantly higher probability of accepting a COVID-19 vaccination.

The results are similar for respondents who do not or only partially agree with the statement that everyone should receive the recommended vaccines, being significantly less likely to have already been vaccinated against COVID-19 (Table 4). Further, people who

were vaccinated against influenza in the winter of 2020/2021 have a significantly higher probability of having already received a COVID-19 vaccine (Table 4).

Table 3. Multinomial logistic regression of attitudes towards vaccinations associated with intent to receive a COVID-19 vaccine.

	Vaccination Intent				
"I think it's important that everyone receives the recommended vaccinations." *	**Yes (ref.)**	**No**		**Maybe**	
	n	***n*** **RR**	**95% CI**	***n*** **RR**	**95% CI**
Disagree/rather disagree	13	65 529.500	223.704–1253.308	32 50.130	24.840–101.169
Partly agree	32	7 23.166	8.288–64.753	50 31.821	18.846–53.728
"When you hear a negative comment about vaccine(s), do you: . . . ..?" **	**Yes (ref.)**	**No**		**Maybe**	
	n	***n*** **RR**	**95% CI**	***n*** **RR**	**95% CI**
"Ask for the opinion(s) of those in your private environment"—no	862	60 0.685	0.392–1.194	89 0.486	0.319–0.740
"Get the opinion of a doctor or healthcare professional"—no	799	65 1.610	0.890–2.912	100 1.281	0.824–1.992
"Check the correctness of the statements through media reports"—no	328	30 1.421	0.741–2.725	43 0.997	0.606–1.638
"I do not (often) deal with negative comments"—no	865	73 2.393	1.041–5.499	111 1.111	0.638–1.935
"No answer"—no	1038	69 0.524	0.211–1.301	120 0.480	0.219–1.054
"I engage with the person expressing the negative comment"—no ***	1097	82		1134	
"Did you get vaccinated against influenza in 2020/21 season?" ****	**Yes (ref.)**	**No**		**Maybe**	
	n	***n*** **RR**	**95% CI**	***n*** **RR**	**95% CI**
"Yes"	665	13 0.124	0.068–0.228	29 0.182	0.119–0.280
"No" (ref.)	439	69		105	
All (not yet vaccinated)	**1104**	**82**		**134**	

* AIC = 39.633, BIC = 70.746 (unadjusted model); Reference category. Agree/rather agree; ** Multiple choice question, AIC = 151.188 BIC = 161.558; Reference category in each item is the answer "yes" to executing the given action; *** Too few cases to allow for analysis; **** AIC = 29.799 BIC = 50.541.

Table 4. Binomial logistic regression of attitudes towards vaccinations associated with negative COVID-19 vaccination status.

"To What Extent Do You Agree with the Following Statement? "	**Vaccination Status (Not Vaccinated)**			
"I find it important for everyone to receive the recommended vaccinations" *	***n***	**OR**		**95% CI**
Disagree/rather disagree	110	0.138	.	0.080–0.237
Partly agree	89	0.577	.	0.385–0.865
"When you hear a negative comment about vaccine(s), do you . . . .." **	***n***	**OR**		**95% CI**
"Ask for the opinion(s) of those in your private environment"—no	1011	1.134	.	0.903–1.424
"Get the opinion of a doctor or healthcare professional"—no	964	0.893	.	0.721–1.105
"Check the correctness of the statements through media reports"—no	401	1.218	.	0.953–1.557

Table 4. *Cont.*

"To What Extent Do You Agree with the Following Statement? "		Vaccination Status (Not Vaccinated)		
"I do not (often) deal with negative comments"—no	1049	0.893	.	0.689–1.158
"No answer"—no	1227	2.558	.	1.597–4.096
"I engage with the person expressing the negative comment"—no ***	1313	–		–
All	**1320**			

* Cox and Snell R-Quadrat = 0.248; Nagelkerkes R-Quadrat = 0.331 (adjusted model for age, sex, education, occupation); Reference category; Agree/rather agree; ** Multiple choice question, Cox and Snell R-Quadrat = 0.234; Nagelkerkes R-Quadrat = 0.312; Reference category in each item is the answer "yes" to executing the given action (*** too few cases to allow for analysis).

3.2. Attitude towards Other Non-Pharmaceutical Interventions Following A COVID-19 Vaccination

We examined whether the vaccination status is associated with a certain attitude towards NPIs (e.g., mask mandate, visitor regulations) at the LMU University hospital (Table 5). HCW who agreed with preventative measures remaining until the end of 2021 were more likely to have already been vaccinated. However, HCW who did not agree or only partially agreed with extending the measures to 2022, as well, were less likely to have already been vaccinated against COVID-19. Further, HCW who did not agree with extending the offer for free PCR-testing at the hospital despite the progress of the vaccination campaign were more likely to not have been vaccinated.

Table 5. Binomial logistic regression of negative COVID-19 vaccination status associated with the attitudes towards other implemented non-pharmaceutical interventions.

"In General, Regarding the COVID-19 Vaccination Campaign, It Is Important for Me..." *		Vaccination Status (Not Vaccinated)		
"...that the current measures at LMU University Hospital (e.g., mask mandate) remain valid until the end of 2021"	***n***	**OR**		**95% CI**
Disagree	90	0.739	.	0.441–1.238
Rather disagree	85	0.845	.	0.522–1.365
Partly agree	235	1.104	.	0.809–1.506
Rather agree	347	1.302	.	1.009–1.681
"...that the current measures at LMU University Hospital (e.g., mask mandate) remain valid in 2022 as well"	***n***	**OR**		**95% CI**
Disagree	210	0.723	.	0.479–1.092
Rather disagree	216	0.634	.	0.441–0.912
Partly agree	439	0.715	.	0.533–0.958
Rather agree	228	0.833	.	0.608–1.140
"...that testing at the LMU University Hospital should remain broadly available regardless of the vaccination campaign"	***n***	**OR**		**95% CI**
Disagree	34	0.339	.	0.145–0.748
Rather disagree	23	0.583	.	0.273–1.245
Partly agree	76	1.007	.	0.654–1.550
Rather agree	361	0.925	.	0.654–1.550
All	1320			

* Cox and Snell R-Quadrat = 0.237; Nagelkerkes R-Quadrat = 0.316 (adjusted model for age, sex, education, occupation); the distribution of answers allowed for testing without merging any categories; Reference category in each item is the answer "Agree".

3.3. Factors Associated with Vaccination Intent (Informed by the Health Belief Model)

3.3.1. Perceived Susceptibility

We tested the perceived susceptibility to COVID-19 with five items assessing one's perceived likelihood to get infected as well as one's attitude change towards the likelihood of getting infected in a private or professional setting since the beginning of vaccination ($\alpha = 0.509$) [14]. HCW who disagreed or rather disagreed with the statement that they were less worried about attracting COVID-19 in a professional setting compared to before the

start of the vaccination campaign had a significantly higher likelihood of not intending to receive a COVID-19 vaccine (Table 6) or being still undecided on the matter. HCW who partially agree with the statement are significantly more likely to be undecided regarding a COVID-19 vaccine.

Table 6. Multinomial logistic regression models with the Health Belief Model factors associated with intent to receive a COVID-19 vaccine.

Perceived Susceptibility Is a Predictor for Getting a COVID-19 Vaccine *	**Vaccination Intent**				
α = 0.509 AIC = 703.718, BIC = 714.088	**Yes (ref.)**	**No**		**Maybe**	
"How do you rate the following aspects from your personal point of view?" "In regard to the spread of COVID-19 the likelihood that I myself be will infected is..."	***n***	***n*** **RR**	**95% CI**	***n*** **RR**	**95% CI**
Very low/Low	337	51 0.989	0.378–2.589	58 1.498	0.691–3.247
Medium	571	21 0.498	0.194–1.278	62 0.954	0.474–1.918
"Since the vaccination campaign started, I've been more afraid of getting infected in my private environment than before or I've been more afraid for my loved ones."	***n***	***n*** **RR**	**95% CI**	***n*** **RR**	**95% CI**
Disagree/Rather disagree	892	76 0.862	0.290–2.560	106 0.736	0.334–1.625
Partly agree	152	2 1.007	0.239–4.250	20 0.918	0.362–2.326
"Since the vaccination campaign started, I've been less afraid of getting infected in my private environment than before or I've been less more afraid for my loved ones."	***n***	***n*** **RR**	**95% CI**	***n*** **RR**	**95% CI**
Disagree/Rather disagree	571	70 2.155	0.894–5.196	90 1.905	0.947–3.833
Partly agree	255	2 0.456	0.122–1.699	31 1.909	0.899–4.057
"Since the vaccination campaign started, I've been less afraid of getting infected in my professional environment than before."	***n***	***n*** **RR**	**95% CI**	***n*** **RR**	**95% CI**
Disagree/Rather disagree	575	71 3.094	1.180–8.114	93 3.231	1.527–6.839
Partly agree	248	3 0.595	0.205–2.479	30 2.283	1.051–4.961
"Since the vaccination campaign started, I've been more afraid of getting infected in my professional environment than before."	***n***	***n*** **RR**	**95% CI**	***n*** **RR**	**95% CI**
Disagree/Rather disagree	925	78 6.007	1.909–18903	109 2.411	0.998–5.826
Partly agree	124	2 1.542	0.500–4.755	18 2.165	0.961–4.879
Perceived severity is a predictor for a getting a COVID-19 vaccine α = 0.817 AIC = 82.230 BIC = 134.084	**Yes (ref.)**	**No**		**Maybe**	
"How do you rate the following aspects from your personal point of view?" "In regard to the spread of COVID-19 the probability of me getting sick from COVID-19 is..."	***n***	***n*** **RR**	**95% CI**	***n*** **RR**	**95% CI**
Very low/Low	370	60 2.114	0.805 –5.551	59 2.262	1.006–5.082
Medium	562	16 0.497	0.183–1.353	65 1.706	0.798–3.647

Table 6. *Cont.*

Perceived Susceptibility Is a Predictor for Getting a COVID-19 Vaccine *		**Vaccination Intent**			
"In regard to the spread of COVID-19 the probability of me getting seriously ill from COVID-19 is..."	***n***	***n*** **RR**	**95% CI**	***n*** **RR**	**95% CI**
Very low/Low	654	72 7.874	0.952–65.149	91 1.538	0.581–4.070
Medium	342	9 3.981	0.464–34.146	37 1.446	0.546–3.830
Perceived benefits are a predictor for a getting a COVID-19 vaccine	**Yes (ref.)**	**No**		**Maybe**	
AIC = 40.631 BIC = 71.743			**95% CI**		**95% CI**
"I am completely convinced of the effectiveness of the COVID-19 vaccines"	*n*	*n* RR		*n* (RR; *p*-value)	
Disagree/Rather disagree	17	63 485.471	194.154 −1213.891	46 72.979	37.977–140.241
Partly agree	170	12 9.247	3.589–23.824	54 8.567	5.412–13.561
Perceived barriers are a predictor for a getting a COVID-19 vaccine	**Yes (ref.)**	**No**		**Maybe**	
α = 0.845 AIC = 93.445 BIC = 145.299	***n***	***n*** **RR**	**95% CI**	***n*** **RR**	**95% CI**
"I am completely convinced of the safety of the COVID-19 vaccines"					
Disagree/Rather disagree	33	71 116.829	28.676–475.969	59 20.484	9.584–43.781
Partly agree	215	8 5.423	1.230–23903	57 5.938	3.115–11.322
"I have no concerns regarding the COVID-19 vaccines"					
Disagree/Rather disagree	93	73 10.264	2.916–36133	81 7.890	3.924–15.866
Partly agree	215	5 10.264	0.348–6.924	36 2.744	1.366–5.513
All	**1104**	**82**			**134**

* Reference category in each item is the highest answer on the merged Likert scale ("Rather agree/Agree" or "High / Very high"); adjusted model for age, sex, education, occupation.

For vaccination status, HCW who disclosed to being less worried about getting infected in their professional or personal setting since the beginning of vaccination were more likely to have already received one or both vaccination doses (Table 7).

3.3.2. Perceived Severity of Disease in Case of Attraction of COVID-19

For perceived severity, we tested two items (α = 0.817). Unlike perceived susceptibility, the items for perceived severity demonstrated only one borderline significance towards vaccination intent, where people who identify their risk of getting sick from COVID-19 as low or very low were significantly more likely to be undecided (Table 6).

In terms of vaccination status, the data showed that persons who define their risk of getting sick from COVID-19 as very low or low are more likely to have already been vaccinated (Table 7).

3.3.3. Perceived Benefits

The perceived benefits were measured with one item assessing the individual's conviction of the effectiveness of COVID-19 vaccines (Table 6). The data in the better fitting unadjusted model showed a strong significant effect of low or partial conviction of the effectiveness of COVID-19 vaccines on the vaccination intent. Further, persons who are not

or only partially convinced of the effectiveness are significantly more likely to be undecided on getting a COVID-19 vaccine than those who are rather or completely convinced.

The results are also reflected in the better fitting model adjusted for age, sex, education and occupation for outcomes for vaccination status, where HCW who are not or are only partially convinced of the effectiveness of COVID-19 vaccines are less likely to have already received a dose (Table 7).

Table 7. Binomial logistic regression models with the Health Belief Model factors associated with intent to receive a COVID-19 vaccine.

Perceived susceptibility is a predictor for getting a COVID-19 vaccine [1,*]	**Vaccination status (not vaccinated)**			
"How do you rate the following aspects from your personal point of view?" "In regard to the spread of COVID-19 the likelihood that I myself be will infected is..."	***n***	**OR**		**95% CI**
Very low/Low	446	0.644	.	0.430–0.965
Medium	654	0.920	.	0.654–1.295
"Since the vaccination campaign started, I've been more afraid of getting infected in my private environment than before or I've been more afraid for my loved ones."				
Disagree/Rather disagree	1074	1.484	.	0.915–2.406
Partly agree	174	1.134	.	0.640–2.007
"Since the vaccination campaign started, I've been less afraid of getting infected in my private environment than before or I've been less afraid for my loved ones."				
Disagree/Rather disagree	731	0.432	.	0.323–0.577
Partly agree	288	0.670	.	0.497–0.902
"Since the vaccination campaign started, I've been less afraid of getting infected in my professional environment than before."				
Disagree/Rather disagree	739	0.249	.	0.187–0.332
Partly agree	281	0.525	.	0.395–0.697
"Since the vaccination campaign started, I've been more afraid of getting infected in my professional environment than before."				
Disagree/Rather disagree	489	1.818	.	1.184–2.791
Partly agree	643	1.011	.	0.692–1.477
Perceived severity is a predictor for a getting a COVID-19 vaccine **	**Vaccination status (not vaccinated)**			
"In regard to the spread of COVID-19 the probability of me getting sick from COVID-19 is..."	***n***	**OR**		**95% CI**
Very low/Low	489	1.567	.	1.103–2.226
Medium	643	1.039	.	0.754–1.433
"In regard to the spread of COVID-19 the probability of me getting seriously ill from COVID-19 is..."				
Very low/Low	817	0.848	.	0.556–1.293
Medium	388	0.700	.	0.463–1.058
Perceived benefits are a predictor for a getting a COVID-19 vaccine ***	**Vaccination status (not vaccinated)**			
"I am completely convinced of the effectiveness of the COVID-19 vaccines"	***n***	**OR**		**95% CI**
Disagree/Rather disagree	126	0.061		0.032–0.118
Partly agree	236	0.554		0.428–0.718
Perceived barriers are a predictor for a getting a COVID-19 vaccine ****	**Vaccination status (not vaccinated)**			
"I am completely convinced of the safety of the COVID-19 vaccines"	***n***	**OR**		**95% CI**
Disagree/Rather disagree	163	0.189		0.107–0.331
Partly agree	280	0.704		0.528–0.939
"I have no concerns regarding the COVID-vaccines"				
Disagree/Rather disagree	247	0.436		0.296–0.642
Partly agree	256	0.739		0.555–0.985
All	**1320**			

[1] Reference category in each item is the highest answer on the merged Likert scale ("Rather agree/Agree" or "High/Very high"). * Cox and Snell R-Quadrat = 0.334; Nagelkerkes R-Quadrat = 0.445 ** Cox and Snell R-Quadrat = 0.236; Nagelkerkes R-Quadrat = 0.314 *** Cox & Snell R-Quadrat = 0.264; Nagelkerkes R-Quadrat = 0.352 **** Cox and Snell R-Quadrat = 0.270; Nagelkerkes R-Quadrat = 0.360; unadjusted models.

3.3.4. Perceived Barriers

Perceived barriers were measured with two items ($\alpha = 0.845$). The results demonstrate a strong association between perceived barriers and the vaccination intent (Table 6). Respondents who are not or only partially convinced of the safety of COVID-19 vaccines are significantly more likely to refuse a vaccine or undecided on whether or not to get vaccinated.

We observed similar results for the effect of concerns regarding COVID-19 vaccines on the vaccination intent (Table 6). People who have any concerns regarding the COVID-19 vaccines are significantly more likely to refuse a vaccine. Similarly, those with concerns or partial concerns have a significantly higher likelihood of being undecided.

In terms of vaccination status, the results in the better fitted adjusted model showed an identical result with people uncertain or concerned regarding COVID-19 vaccines having a higher chance of not being vaccinated (Table 7).

3.3.5. Cues to Action

We analysed the cues to action by examining the link between the COVID-19 vaccination intent and the utilization of media platforms and channels (external cues) as well as the perceived knowledgeability on the topic (internal cues).

Perceived Knowledgeability and COVID-19 Vaccination Intent

We examined how the individual's perceived knowledgeability on COVID-19 vaccines affects the intention to receive one (Table 8). Due to the relatively even distribution of subgroups, we decided against the merger of items as opposed to the other analysed HBM constructs. There was a particularly strong association for disagreeing or completely disagreeing with the statement "I generally felt well informed about COVID-19 vaccines and their safety" and being more likely to not have intent or being undecided on receiving a COVID-19 vaccine.

Table 8. Multinomial logistic regression for the perceived knowledgeability associated with intent to receive a COVID-19 vaccine.

Perceived Knowledgability Is a Predictor of Intent to Receive a COVID-19 Vaccine *	**Yes (ref.)**	**No**		**Maybe**	
"I generally felt well informed about COVID-19 vaccines and their safety"	*n*	*n* RR	95% CI	*n* RR	95% CI
Disagree	30	24 25.900	10.690–62.752	22 21.104	8.906–50.008
Rather disagree	111	18 5.250	2.217–12.431	32 8.296	3.833–17.958
Partly	271	18 2.150	0.919–5031	45 4.779	2.290–9.972
Rather agree	433	14 1.047	0.433–2.529	26 1.728	0.797–3.745
All	**1104**	**82**		**134**	

* AIC = 66.316 BIC = 118.170; Reference category: "Agree" (unadjusted).

Utilization of Certain Media Platforms or Channels and Perceived Knowledgeability

We examined how the utilization of different media platforms or channels (both private, state, official and other channels) affects one's perception of knowledgeability regarding COVID-19 vaccines with a generalized linear model (Table 9). Not discussing the topic of vaccination with other people as well as not getting involved in personal conversations with family members, friends or acquaintances was linked to a likely increase in perceived knowledge about COVID-19 vaccines. Similarly, seeking information specifically on vaccines may increase one's perception of knowledgeability. On the contrary, perceived knowledgeability may be reduced if one does not turn to the information resources provided by state or federal health authorities or does not discuss vaccinations with the vaccination doctor or with another medical professional.

Table 9. Generalized linear models for the utilization of certain media platforms/channels associated with the perceived knowledgeability regarding COVID-19 vaccines.

Utilization of Certain Media Platforms/Channels and Perceived Knowledgeability *	**Perceived Knowledgeability**		
"What are the most common information platforms you turn to for information on vaccines?"	***n***	**OR**	**95% CI**
Public television channels (e.g., ARD, ZDF, Bayerischer Rundfunk)—"no"	950	1.012	0.861–1.191
Private TV channels (e.g., ProSieben, RTL) – "no"	2355	1.214	0.916–1.609
Daily newspapers (print or online)—"no"	1418	0.863	0.740–1.007
Online media (e.g., other websites)—"no"	1087	1.150	0.985–1.343
Radio—"no"	1981	1.027	0.856–1.231
Social networks (e.g., Facebook, Twitter)—"no"	2312	1.011	0.784–1.302
Podcasts—"no"	2267	1.011	0.802–1.276
Personal conversations with other people—"no"	1363	1.184	1.006–1.392
I do not seek specific information about vaccinations—"no"	2356	1.352	1.005–1.820
Utilization of certain media platforms/channels and COVID-19 vaccination intent **			
"What are the most common information channels you turn to for information on vaccines?" **	***n***	**OR**	**95% CI**
Scientific sources, e.g., peer-reviewed articles, reports of clinical trials—"no"	1306	1.024	0.873–1.201
Information from state or federal authorities (e.g., Federal Center for Health Education, Paul Ehrlich Institute or Robert Koch Institute)—"no"	826	0.772	0.650–0.917
Information from international organizations, e.g., World Health Organization—"no"	1846	1.099	0.925–1.305
Personal conversation with the (vaccinating) doctor or a medical professional (incl. the vaccinating healthcare professionals at the hospital's vaccination centre)—"no"	2464	0.835	0.708–0.986
Information from health insurance companies—"no"	2282	0.926	0.620–1.382
Information from the local health department—"no"	2282	0.927	0.729–1.179
Information from pharmaceutical companies—"no"	2374	0.917	0.688–1.222
Information events, e.g., meetings with experts—"no"	2237	0.936	0.750–1.167
Personal conversations with family members, friends or acquaintances, colleagues—"no"	1663	1.233	1.044–1.457
I do not seek specific information channels to inform myself about vaccinations—"no"	2417	1.402	0.975–2.017
All	**2555**		

* Pearson's Chi = 0.981 (GLM); ** "leftover"; Multiple choice questions; Reference category in each item is the answer "yes" to utilizing the given channel or platform.

Utilization of Certain Media Platforms or Channels and The COVID-19 Vaccination Intent

We conducted the same analysis for the COVID-19 vaccination intent using a multinomial logistic regression (Table 10). For media platforms, the model showed a strong association between not using public television channels and refusing a COVID-19 vaccine. Not using social media networks or personal conversations with other people as an information source was linked to a lower risk of denying COVID-19 vaccination. Regarding indecisiveness, not using daily newspapers and podcasts was linked to a higher probability whereas not conversing with others was associated with a lower likelihood of being undecided.

Table 10. Multinomial logistic regression models for the utilization of certain media platforms/channels associated with the intent to receive a COVID-19 vaccine.

Utilisation of certain media platforms/channels correlates with the intent to receive a COVID-19 vaccine *	**Yes (ref.)**	**No**		**Maybe**	
"What are the most common information platforms you turn to for information on vaccines?"	***n***	***n*** **RR**	**95% CI**	***n*** **RR**	**95% CI**
Public television channels (e.g., ARD, ZDF, Bayerischer Rundfunk)—"no"	350	57 3.253	1.838–5.754	54 1.131	0.737–1.736
Private TV channels (e.g., ProSieben, RTL)—"no"	1008	73 0.619	0.266–1.442	124 (1.511; 0.267)	0.728–3.136
Daily newspapers (print or online)—"no"	596	61 1.811	0.999–3.283	97 2.282	1.482–3.514
Online media (e.g., other websites)—"no"	495	33 1.161	0.651–2.070	57 (0.992)	0.653–1.505
Radio—"no"	830	71 1.461	0.710–3.004	104 1.127	0.708–1.794
Social networks (e.g., Facebook, Twitter)—"no"	1004	60 0.308	0.166–0.571	123 (1.251; 0.520)	0.632–2.479
Podcasts—"no"	970	72 1.233	0.568–2.674	129 2.986	1.176–7.585
Personal conversations with other people—"no"	636	40 0.717	0.411–1.251	54 (0.516; 0.003)	0.335–0.794
I do not seek specific information about vaccinations—"no"	1027	64 0.591	0.275–1.270	115 0.683	0.442–1.708
"What are the most common information channels you turn to for information on vaccines?" **	**Yes (ref.)**	**No**		**Maybe**	
	n	***n*** **RR**	**95% CI**	***n*** **RR**	**95% CI**
Scientific sources, e.g., peer-reviewed articles, reports of clinical trials—"no"	627	37 0.526	0.295 - 0.936	85 1.045	0.688–1.587
Information from state or federal authorities (e.g., Federal Center for Health Education, Paul Ehrlich Institute or Robert Koch Institute)—"no"	355	55 3.434	1.926–6.123	60 1.339	0.862–2.079
Information from international organizations, eg. World Health Organization—"no"	798	58 0.507	0.275–0.935	97 0.685	0.432–1.087
Personal conversation with the (vaccinating) doctor or a medical professional (incl. the vaccinating healthcare professionals at the hospital's vaccination centre)—"no"	814	65 1.156	0.618–2.162	104 1.403	0.878–2.241
Information from health insurance companies—"no"	1065	79 0.752	0.193–2.937	126 0.459	0.194–1.088
Information from the local health department—"no"	982	76 1.791	0.666–4.822	119 0.937	0.508–1.728
Information from pharmaceutical companies—"no"	1043	71 0.413	0.184–0.928	129 1.241	0.469–3.283
Information events, e.g., meetings with experts—"no"	982	68 0.583	0.292–1.163	123 1.199	0.608–2.364
Personal conversations with family members, friends or acquaintances, colleagues—"no"	742	46 0.598	0.346–1.034	64 0.448	0.293–0.686
I do not seek specific information channels to inform myself about vaccinations—"no"	1046	68 0.372	0.151–0.919	116 0.334	0.158–0.707
All	**1104**	**82**			**134**

* AIC = 1134.876 BIC = 1331.92; ** "leftover"; Reference category in each item is the answer "yes" to utilizing the given channel or platform (unadjusted).

Further, not utilizing scientific sources, information from international organizations and pharmaceutical companies was found to reduce the risk of COVID-19 vaccine refusal. In contrast, not utilizing the information sources provided by state or federal health authorities was linked to a higher likelihood of vaccine refusal.

Supplement A provides insights into the demands and expectations of participants regarding the design and contents of vaccine-related information and messages. Furthermore, statistics on the utilization of internal communication and information services are provided.

4. Discussion

The presented study shows an in-depth analysis of COVID-19 vaccination intent and vaccination status of HCW in one of the largest university hospitals in Germany at the beginning of the vaccination campaign (25 February to 20 March 2021); in comparison to a survey conducted prior to the authorization of any COVID-19 vaccine, vaccination intent in our cohort had increased [7]. Our data show that a generally approving attitude towards recommended vaccines and having been vaccinated against influenza in the winter of 2020/2021 were strongly associated with COVID-19 vaccination intent. Further, HCW that had already received at least one vaccine dose were more likely to agree with extending NPIs until the end of 2021. However, HCW not yet vaccinated were more likely to disagree or only partially agree with continuing the NPIs (including free PCR-testing) in 2022. Our HBM-based analysis of the factors influencing the decision-making processes on COVID-19 vaccination demonstrated particularly strong associations between perceived benefits and barriers and the refusal or indecisiveness regarding reception of the vaccine. Unchanged or rather low perceived susceptibility and severity were associated with reluctance or indecisiveness. In the analysis of cues to action, the results showed that HCW who perceive themselves as ill-informed about COVID-19 vaccines and their safety are significantly more likely to refuse vaccination or to be undecided. Factors associated with an increase in perceived knowledgeability regarding COVID-19 vaccines were not conversing with others (e.g., family members, acquaintances) but rather seeking specific information on the topic. A reduction in the perceived knowledgeability was observed in cases where information provided by sources such as state or federal health authorities as well as by healthcare professionals was not utilized. Further, there was a significant association between not conversing with others on the topic and being less likely to refuse or be undecided on whether or not to get vaccinated, similar to the results for the effect of personal conversations on one's perceived knowledgeability. Not using social media as an information channel was linked to a lower likelihood of COVID-19 vaccination refusal.

The results of this study contribute to the existing body of evidence on the intention and reasoning behind a vaccination decision of HCW in a pandemic context beyond COVID-19 [15]. The COVID-19 vaccination intent and status among the examined HCW cohort after the beginning of the vaccination campaign in Germany amplifies the evidence outlined by similar cross-sectional self-administered surveys among HCW, as these were conducted primarily prior to, rather than after, the approval of any COVID-19 vaccine. Two surveys among healthcare personnel in university hospitals in Italy and France present an intent to receive a COVID-19 vaccine of over 75% of respondents [19,20]. In a nationwide disseminated questionnaire in Italy, the results indicated a slightly lower rate, with 67% of respondents intending to vaccinate against COVID-19 as soon as a vaccine was available, 27.7% feeling uncertain and 7.3% refusing a vaccine [21]. A similar percentage (28.4%) of reluctance towards COVID-19 vaccines was reported among French-speaking HCW in France, Belgium and Canada [22]. A rather inhomogeneous vaccination intent was reported by six surveys conducted among HCW in hospital settings outside of Europe, with COVID-19 vaccination acceptance rates ranging between 27.7% and 63.0% [23–28]. A more recent survey conducted in two Vietnamese general hospitals after the approval of several vaccines has shown a significant acceptance of COVID-19 vaccines of 76.10% [29]. The comparably high COVID-19 vaccination intent identified in our analysis might suggest

a longitudinal shift in HCW COVID-19 vaccination intent after the authorization of the first vaccines. A similar longitudinal shift has been observed by two German-wide surveys on HCW COVID-19 vaccination, where the vaccination intent increased from 65% to 75% between December 2020 and February 2021 in one of the surveys [30] and from 83% in March and April 2021, a period in which the presented data were also collected, to 91% and 92% in the second and third wave, respectively [31–33].

4.1. General Attitude towards Vaccines

Further, participants of the KroCo study, a longitudinal survey on COVID-19 vaccination intent by the Robert Koch Institute, also placed their main arguments against a COVID-19 vaccine in the concerns regarding side effects or even long-term damage as well as uncertainty regarding the vaccine's technology. The main reasons for receiving a COVID-19 vaccine were similarly related to protecting one's health as well as their close ones [31–33]. Several international studies observed similar arguments for and against getting a COVID-19 vaccination, with the protection of oneself and close ones being a main driver for and concerns about the safety, efficacy and side effects of vaccines as reasons against it [20,21,26,28,34]. Similar paths of reasoning were also observed in regard to the pandemic H1N1 (pH1N1) vaccination during the 2009/2010 outbreak [35–37]. Similarly, safeguarding one's health and the health of their loved ones were previously identified as the main driver for receiving any vaccine by HCW [38].

At the time of preparation of this manuscript, we could not identify other studies exploring the association between a generally approving attitude towards vaccines and a positive COVID-19 vaccination intent. However, several studies in an international context have also demonstrated a significant relationship between seasonal influenza vaccination uptake and COVID-19 vaccination intent, corresponding to our findings [20,21,24,26,39]. In a historical analogy, a seasonal influenza vaccination was found to be a common predictor for intending to a receiving a pH1N1 influenza vaccination [15,35–37].

4.2. Attitudes towards Non-pharmaceutical Interventions

At the moment of preparation of these results, we could not identify other studies that had explored the association between COVID-19 vaccination status and attitude towards pandemic-related NPI in HCW populations. Thus, the outcomes presented here provide a reference for future research on the association between attitudes towards COVID-19 pharmaceutical and non-pharmaceutical measures.

4.3. Health Belief Model Constructs

Our findings concerning the HBM factors, however, build upon previously published theoretical and empirical evidence [8,9,40]. Wong et al. observed a very strong association between the items for perceived benefits and a COVID-19 vaccination intent [17]. Perceived benefits and severity were also positively correlated in a population-based study by Wong et al., while the perceived barriers showed a strong negative association with COVID-19 vaccination intent [16]. Similarly, a HBM-based study among Vietnamese HCW reported strong associations for cues to action, perceived benefits and barriers (negative association), whereas the association for perceived susceptibility and severity was relatively weaker [29].

Beyond the COVID-19 vaccine, the perceived benefits as well as the cues to action were identified by Shahrabani et al. as main HBM drivers for seasonal influenza vaccination among HCW in Israel [41].

It is important to note that when exploring potential COVID-19 vaccine decision drivers outside of HBM, several studies identified the perceived individual risk of COVID-19 (often using a factor combing perceived susceptibility and severity) as a strong predictor for HCW for receiving a COVID-19 vaccine [20,21,24]. The systematic review by Ahmad et al. further highlights the distrust in a vaccine's content, safety, efficacy and side-effects as factors associated with vaccine hesitancy among HCW [42]. As these studies were

conducted without the inclusion of other HBM constructs, it is not possible to reflect on the other potentially related factors.

In order to reflect on the fast-paced information background of COVID-19 vaccination campaigns, we attempted an itemized analysis of potential cues to action. Our data support previously published evidence on the significant correlation between cues to action and vaccination intent. In the study by Huynh et al., the cues to action account for the strongest association with a COVID-19 vaccination intent, although no further detail on the specific cues is provided [29]. We found that not utilizing the information provided by state or federal health authorities or not discussing vaccinations with the vaccination doctor or with another medical professional reduces the perceived knowledgeability regarding COVID-19 vaccines, which in turn reduces the likelihood of a vaccination intent. These results build a valuable analogy to the cues to action associated with a COVID-19 vaccination intent among the general population [16]. Further, corresponding to our results on the negative association between social media utilization and vaccination intent, Di Gennaro et al. observed that Italian HCW who were primarily using Facebook as an information source were significantly more likely be hesitant regarding a COVID-19 vaccine [21]. The utilization of social media platforms and its effect on one's motivation to adopt preventive measures, more particularly a vaccination, has been previously examined through the lens of risk perception. However, the results on how and why social media usage affects COVID-19 risk perception, especially the intent to receive a COVID-19 vaccine, vary strongly depending on the target group and setting [43–45].

4.4. Limitations

Several limiting factors need to be taken into account when interpreting the results of this study. As to the survey design and conduction, only approximately one third of employees filled out the questionnaire of IMPF^{LMU}. Further, occupational groups who are working at various locations at the hospital (e.g., logistics, hospital hygiene, catering services) participated less in the study. Due to the rapid rollout of the vaccination campaign at LMU University Hospital, the presented survey could not be launched before the beginning of vaccination. Consequently, a large proportion of the target population had already been vaccinated once when the survey was launched. This disrupted the initial timeline and lead to the addition of the fourth response option ("I have already received one or both of the vaccination doses") to the question on vaccination intent. Further, changes in attitude may have occurred following the beginning of the vaccination campaign or after being vaccinated. Although the majority of the participants noted that information in the German language is sufficient, it is quite possible that the linguistic diversity of the hospital's personnel was not well reflected among the study participants. Recent studies indicate that language barriers as well as ethnical and cultural differences significantly contribute to vaccine hesitancy [39,46].

Concerning results, the differences in subgroup sizes pose a challenge for the interpretation of the results. In addition, we cannot exclude the impact of social desirability bias as well as of central tendency bias on the responses of participants [47,48].

HBM-based analyses rest upon the psychosocial assumption of health being considered of high priority by the targeted population [49]. Although the results of this study do indicate a strong prioritization of one's personal health as a facilitator for receiving a COVID-19 vaccine, further health and non-health related factors that may also influence the decision-making process but go beyond the scope of HBM should be considered in future research attempts. Relevant health-related factors in this sense include the health and well-being of persons in one's professional (e.g., patients) and private network (e.g., family). Furthermore, non-health related factors represent a potential confounding aspect in HBM-based analyses. Additional aspects that could not be taken into consideration due to the cross-sectional design of this study are the potential change of attitude towards COVID-19 vaccines throughout the vaccination campaign, and the COVID-19 vaccination mandate for HCW adopted on 10 December 2021. Especially since the recommendations

of the European Medicines Agency (EMA) as well as of Germany's Standing Committee on Immunization (STIKO) underwent several updates in the first half of 2021, changes in attitude towards specific vaccines or COVID-19 vaccines in general are possible [50,51]. A further analysis into the cues to action would have been possible with a more detailed section on the utilization of information platforms and channels, as there are quantitatively and qualitatively diverse possibilities for employing information sources when actively or passively seeking information. This limitation is particularly valid in regard to social media utilization in terms of misinformation and infodemic management [49,52].

It should be noted that the presented study did not consider the possibility of a COVID-19 vaccination mandate for HCW and the therewith-associated labor and economic factors. The respective legislation was adopted on 10 December 2021 and binds a working contract in any healthcare institution to a complete COVID-19 vaccination as of 16 March 2022 [53].

5. Conclusions

Our findings provide insights into the vaccination intent and status of COVID-19 vaccines among HCW as well as on the reasons and factors affecting these. Our results can serve as guidance for the design of vaccination campaigns among HCW in similar organizational contexts as well as for the management of future epidemic or pandemic outbreaks. Further, the pronounced evidential comparisons between the vaccination intent and attitudes of HCW during the H1N1 and the COVID-19 pandemic indicate the existence of a pattern-oriented behaviour beyond contextual parameters. These indications would call for a holistic approach towards improving and accelerating the adoption of novel pharmaceutical measures (i.e., vaccines) by HCW through preventively addressing the here outlined determinants, barriers and modifiers of vaccination intent.

Appropriately, our study contributes towards the development of a framework for health promotion communication targeted at HCW by identifying the specific aspects of HBM factors that could be addressed most efficiently. Further, the operationalization of HBM in this study caters to the empirical evidence for the application of the model in a healthcare setting within a pandemic context, particularly by presenting an in-depth perspective on the parameters and mechanism of impact of cues to action.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/vaccines10081231/s1, Supplement A: The following tables provide further insights into the data collected through the implemented questionnaire. The data refers to the utilization of information sources within the LMU University hospital. Supplement B: The following tables present the tested models that were not chosen for interpretation due to their poor model fit compared to the other model(s) chosen for interpretation. .

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Informed Consent Statement: Informed consent was obtained by all participants in an electronic form. Filling out the questionnaire was possible only after agreeing to the data usage notice approved by the Data Protection Officer of the LMU University Hospital.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to the data protection policy of the LMU University Hospital.

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6. Paper II

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Are We Prepared for the Next Pandemic? Management, Systematic Evaluation and Lessons Learned from an In-Hospital COVID-19 Vaccination Centre for Healthcare Workers

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Abstract: Background: the organisation of a COVID-19 vaccination campaign for healthcare workers (HCWs) within a university hospital presents a challenge of a particularly large scale and urgency. Here, we evaluate the in-hospital vaccination process and centre for HCWs at LMU University Hospital in Munich, Germany. Methods: We executed a mixed-method process evaluation of the vaccination centre at LMU University Hospital during the first COVID-19 vaccination campaign. In a programme monitoring, we continuously assessed the implementation of the centre's operational management including personnel resources. In evaluating the outreach to and satisfaction of the target group with the centre and process, we executed two anonymous surveys aimed at the HCWs vaccinated at the in-hospital centre (1) as well as centre staff members (2). Results: staff numbers and process time per person were reduced several times during the first vaccination campaign. Lessons concerning appointment scheduling were learned. HCWs vaccinated at the in-hospital centre were satisfied with the process. A longer waiting time between admission and inoculation, perceived dissatisfying accessibility as well as an increased frequency of observed adverse events were linked to a reduced satisfaction. Comparatively subpar willingness to adhere to non-pharmaceutical measures was observed. Centre staff reported high satisfaction and a workload relatively equal to that of their regular jobs. Our outcomes provide references for the implementation of an in-hospital vaccination centre in similar settings.

Keywords: COVID-19; vaccination centre; healthcare workers; occupational health

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1. Introduction

Vaccinations are among the most effective preventive measures against COVID-19 [1,2]. Once the first COVID-19 vaccines were approved by the European Union authorities, the roll-out of the vaccination campaign in Germany began promptly and under a legally

binding prioritisation [3,4]. With healthcare workers (HCWs) being among the top-priority groups to be inoculated, the logistics and organisation of the vaccination campaign within hospitals were mostly delegated to the hospitals themselves. In the state of Bavaria, a legal framework between the state and the Bavarian Hospital Association was set to define the scope and parameters of the hospitals' mandate to coordinate the inoculations of their employees [5].

As one of the largest hospitals in Germany, the Ludwig Maximilian University (LMU) Hospital was faced with assembling a large-scale vaccination centre within days following the authorisation of the first COVID-19 vaccines by the European Medicines Agency [4]. Due to the rapid setup of the vaccination centre and the lack of opportunity for pilot testing the processes prior to implementation, there were no insights into how well the centre would function. Furthermore, the organisation of a single vaccination centre under the given prerequisites presented a sharp divergence from the established practices at the hospital, where vaccination campaigns (e.g., against influenza) have been routinely set up in a decentralised form with no need for a follow-up visit. Accordingly, it was uncertain how this new form of a vaccination process for the LMU University Hospital would be perceived by its employees and if there were any factors affecting the satisfaction with the process.

Therefore, this paper aims to explore the feasibility of the first-of-its-kind large-scale COVID-19 vaccination centre at the LMU University hospital and assess managerial and implementation aspects that may help facilitate the organisation of in-hospital vaccination centres in similar settings, especially in the context of future outbreak prevention strategies. Further, we analyse the satisfaction of HCWs with the vaccination process and identify potential associated factors that can serve as guidance for the design of vaccination centres for HCWs.

2. Materials and Methods

Within the scope of the LMU University Hospital as well as of this analysis, we define all hospital employees, including non-medical hospital staff and medical students, as HCWs. We present a process evaluation consisting of an appraisal of the vaccination centre's organisation. In addition, we executed 2 online-based anonymous surveys evaluating the HCWs' satisfaction with the organisation of the vaccinations process. The surveys were part of an extensive evaluation of the whole vaccination campaign at LMU University Hospital within the scope of the prospective study IMPF^{LMU} with the first part of the project exploring the COVID-19 vaccination intent and associated factors in HCWs (1 survey) and the second part, presented here, with 2 surveys, focusing on the implementation of the vaccination centre [6]. The results of the first part of the project have already been published [6].

Of the 2 surveys presented here, one was aimed at HCWs who had received at least 1 inoculation (vaccinees) at the in-hospital centre, while the other one targeted HCWs working as staff in the centre. The vaccination centre began operations on 28 December 2020, and remained open until 18 June 2021. This period constitutes the first vaccination campaign against COVID-19 at the LMU University hospital, and is subject to the contents of the following analyses.

2.1. Organisation and Programme Monitoring of the In-Hospital Vaccination Centre

The in-hospital vaccination centre was organised in accordance with the guidelines provided by the Bavarian State Ministry of Health as well as with the recommendations of the Bavarian State Office for Health and Food Safety [7,8]. The centre was set up as a one-way street in a spacious, barrier-free area inside the main hospital building, with separate entrances and exits allowing for an isolated flow for incoming and outgoing vaccinees. There was no intersection with patient care. The space was equipped with a secure network and telephone connection.

In the admission area located at the entrance, the vaccinees were registered and their COVID-19 vaccination history and recovery status were prompted. Next, the inoculations

were given in private cubicles mainly by physicians. Lastly, vaccinees were asked to rest for 15 min in the observation area, located near the emergency equipment and the nearest exit to the emergency department. The vaccinations were prepared mainly by nursing staff and, for hygienic reasons, outside the main area. Opening hours of the centre were from 9 am to 3 pm with occasional extension to 5 pm. We planned for up to 72 vaccinations per hour.

All HCWs were offered inoculation against COVID-19 in accordance with their professional risk of exposure and with the health authorities' prioritisation scheme. During the first vaccination campaign, the centre inoculated solely with the Comirnaty® vaccine [9]. The appointment scheduling was arranged using a HTML5 booking system by Mayflower GmbH [10]. For any inquiries or comments concerning the vaccinations, an email address was set up. Daily briefing and on-demand debriefing sessions allowed for continuous adjustments to the workflow of the centre. Numbers of vaccinees and large-scale amendments of the centre´s organisation were discussed with the hospital board on a regular basis. The vaccination centre's documentation serves as reference for the final data following the end of the campaign. Further details are reported elsewhere [11].

Here, we assess the first COVID-19 vaccination campaign (December 2020–June 2021) at the LMU University hospital, taking into account documentation, observation and emails addressed to the vaccination centre's inbox.

2.2. Satisfaction with the Vaccination Process

The perception of the vaccination process and centre was evaluated within the scope of the prospective study IMPF^{LMU} [6]. For collecting data on the satisfaction with the vaccination process, 2 questionnaires were created using LimeSurvey Version 4.4.12 + 210308. Most items were measured with a 5-point Likert scale (1 (disagreement/dissatisfaction)–5 (agreement/satisfaction)). Both surveys cover the period of the first vaccination campaign at the hospital (December 2020–June 2021) and were communicated by email as well as via the designated intranet page of the project between 14.04.2021 and 30.06.2021. Participation was voluntary and informed consent was obtained in electronic form.

Survey 1 was aimed at hospital employees with at least 1 COVID-19 shot at the in-hospital vaccination centre. It assessed satisfaction with the vaccination process and potentially associated factors. The design of the questionnaire was informed by the SAGE Working Group's guidance on vaccine hesitancy and consisted of 5 sections [12,13]. The questionnaire was communicated via the designated intranet page and was available to the target group between 14.04.2021 and 30.06.2021. The sociodemographic and occupational characteristics of the cohort were tested for associations with the satisfaction with the process as well as with the reported observations of adverse effects following immunization (AEFIs). Statistically significant associations were considered for adjustment in the further analyses. Further, we tested if and how the contextual influences and geographic barriers affected the overall satisfaction with the vaccination process. As a variable for overall satisfaction, we used the 5-point Likert scale item for "The vaccination process at LMU Hospital was generally well organised". We tested for an association between AEFIs after the first and second vaccination dose and the general satisfaction with the process. Further, we examined whether the individual AEFIs were associated with any of the sociodemographic factors that showed significant association with the general observation of AEFIs after the first and second vaccine inoculation. We examined the attitudes and potential attitude changes towards COVID-19 non-pharmaceutical interventions using the mean values and standard deviation of the answers on the 5-point Likert scale, including Cronbach's Alpha for reliability testing.

Survey 2 targeted employees that had worked at the in-hospital vaccination centre since 2020. The design of the questionnaire was informed primarily by the evaluation needs of the hospital and consisted of 4 sections: general organisation and perception of the vaccination process, information about the vaccination process and sociodemographic data. The questionnaire was distributed by the vaccination centre's management team to a mailing list including all persons on the centre's duty roster. The questionnaire was

available between 14.04.2021 and 30.06.2021. Due to the restricted sample size of the vaccination centre staff, we limited the analysis to a descriptive report including the mean values and standard deviation of Likert scale variables as well as Cronbach's Alpha for reliability testing.

3. Results

3.1. Programme Monitoring of the In-Hospital Vaccination Centre

3.1.1. Vaccinations, Personnel and No-Show Rates

Between December 2020 and June 2021, we administered 20,250 vaccine doses amongst the 11,005 active and permanent employees, of which 13,790 (68%) were given to female HCWs, consistent with the higher proportion of women among hospital staff. There were no serious incidents or adverse events after immunization. Vasovagalreactions or near-syncopes were the most common incidents, with a frequency of about 1:1000 vaccinations.

Organisational adjustments were required during the campaign and within the course of continuous resource evaluation, which referred especially to the personnel management, due to an initial overestimation of staff and time needed per inoculation. Within the first days, we recognised that only five instead of ten minutes per inoculation were needed. This allowed for a substantial reduction of the physicians needed for vaccinations from 12 to 6 per 72 scheduled vaccinees per hour. We also switched from a voluntary deployment system to requesting medical staff from individual departments with support from the executive board of the hospital. With growing experience of the staff and decreased need for consultation concerning safety and side effects, we were able to further reduce the inoculation time to 4 minutes, which summed up to 5 vaccinating physicians per 72 scheduled vaccinees/hour, including a 30 min break for each physician. We also found that the consultant who initially used to be permanently on-site as the centre's manager for emergencies and medical inquiries was needed for occasional telephone consultations only.

Administration was initially covered by eight employees and was also reduced, first to six, and later to five employees, similar to the medical personnel adjustments. The time needed to process a registration for vaccination summed up to four minutes per patient as well. Further, the preparation of the vaccinations equated to 2.5 min per dose and required a total of 3 people daily. Lastly, one additional person acted as on-site operation manager, monitoring and directing the processes, onboarding new employees and coordinating organisational problems and logistics. In total, 14 employees covered the vaccination centre on site. Administration and vaccine preparation were each supervised on demand by a designated person. Other staff needed for work in the vaccinations centre´s environment, such as cleaning, security, IT, logistics and engineering staff, should be taken into account.

The finalised layout of the vaccination centre is presented in Figure 1.

We documented no-show and extra-show rates on a daily basis. We observed a maximum no-show rate of 5.8% for the first shot and 5.2% for the second shot. Further, we aimed to accommodate HCWs with an impromptu inquiry, i.e., without an appointment. This occurred mostly at the beginning or end of a vaccination days' series, with a maximum of 10.5% extra-shows for the first, and 12.1% for the second vaccination. Ultimately, we performed a mean of 70 vaccinations/hour (range: 49–84/h). In addition, many HCWs presented at the beginning or after their working hours, as well as during their lunch breaks, independently from the time their appointment was scheduled for. As these HCWs would present within the day they had been scheduled, the irregularity was not documented as no-show or extra-show, but, nevertheless, led to unequal distribution of the work load for the staff on site.

3.1.2. Administrative Organisation

The vaccination appointment booking was initially set up with a low-barrier digital environment without special requirements for personal authorisation via login data. This

method swiftly proved to be error-prone, thus triggering an adjustment of the system towards booking via personalised login and automatic generation of the second appointment as well as an appointment confirmation via SMS. The follow-up (second) appointment was scheduled in accordance with the recommendations by the German Standing Committee on Vaccination (STIKO) and the Federal Institute for Vaccines and Biomedicines (PEI) [14,15]. The hospital's employees were continuously informed about any changes or adaptations to the recommendations as well as to the vaccination process via the hospital's designated intranet page and via newsletter. A detailed evaluation of the communication campaign and tools implemented at the LMU University hospital is published elsewhere [6].

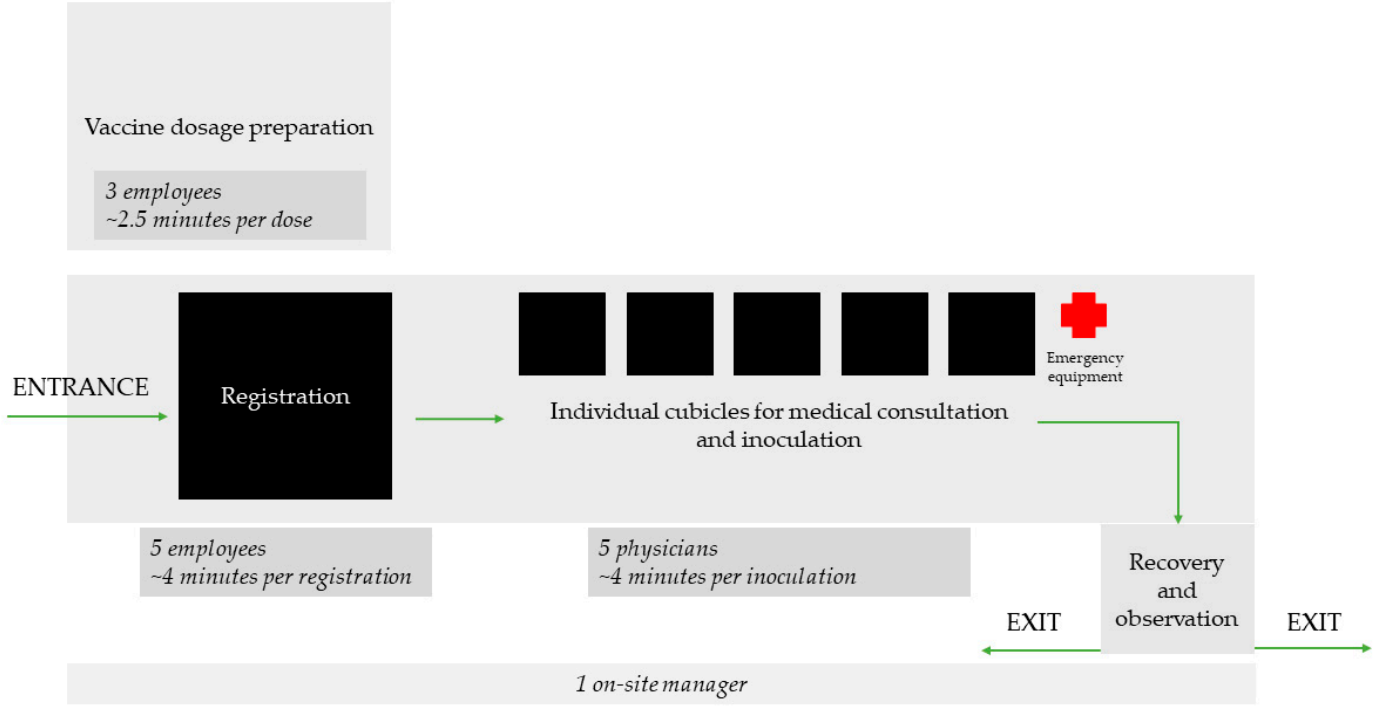

Figure 1. Spatial structure and procedural organisation of the in-hospital vaccination centre of LMU University Hospital after implementing the discussed adaptations to personnel management (December 2020–June 2021).

The email set up for inquiries received up to 80 messages/day (approx. 0.7% of employees). The questions or messages were medical in around 20% of cases, and organisational, e.g., related to scheduling, in approx. 80% of cases. Initially, medical inquiries referred mainly to safety and expected side effects of the vaccine, while later on, reports of assumed and observed AEFIs as well as questions related to individual diseases, pregnancy, breastfeeding and COVID-19 antibodies dominated. The frequently adapted recommendations regarding the intervals between inoculations as well as between inoculations and SARS-CoV-2 infection were a source of numerous inquiries. The answers to organisational inquiries as well as the administrative work initiating from these inquiries was mainly covered by one person from the hospital's administration staff while medical inquiries were handled by the centre's manager as a medical expert.

3.2. Satisfaction with the Vaccination Centre and Process by Vaccinees

Of 11,005 employees, 1662 participated in the survey for vaccinees. Of those, 1035 filled out the questionnaire in full (Table 1). We observed a high satisfaction rate both with the centre as well as with the process—the individual results are presented in below.

The initial testing showed a significant association of age and sex with the reported satisfaction as well as with the observation of AEFIs after the first and second inoculation. Similarly, occupation showed a significant association with satisfaction and reported AEFIs

after the first vaccination dose. Variables with significant associations in the initial testing were used for further analyses in the adjusted models.

3.2.1. Satisfaction with the Process and Vaccine-Specific Issues

The four items for general satisfaction with the vaccination process as well as the nine items for the satisfaction with the individual aspects of the vaccination process demonstrated good reliability (Table 2).

The better fitting unadjusted model showed a link between satisfaction with the vaccination process and accessibility of the vaccination centre and waiting time. Vaccinees dissatisfied with the location of the vaccination centre had a 9.542 higher likelihood of perceiving the vaccination process as rather ill-organised. Further, vaccinees who only partially agreed that the vaccination centre was well accessible had a 5.519 higher likelihood of perceiving the vaccination process as partially ill-organised. Similarly, HCWs not willing to travel over 1 h to the vaccination centre had a 9.502 higher likelihood of perceiving the vaccination process as rather ill-organised (Table 2). Vaccinees that reported a shorter waiting time between registration and inoculation were less likely to perceive the vaccination process as ill-organised. The overall duration of the visit to the vaccination centre did not present any significant association with the satisfaction.

3.2.2. Satisfaction with the Provided Information Sources Prior to Inoculation

We measured the satisfaction of participants with the written information provided upon inoculation (Figure 2). All forms of provided written information demonstrated a satisfactory result, with mean values around "4" ("very helpful"). The four items on satisfaction with medical consultation were only available to those participants who reported that they had requested such consultation upon inoculation (n = 177). The items for perceived safety and confidence with the vaccination process provided similarly consistent results at the upper end of the Likert scale.

3.2.3. COVID-19 Health Behaviour following COVID-19 Vaccination

We measured the attitudes and attitude changes towards COVID-19 non-pharmaceutical interventions (NPI) after receiving both vaccine doses (Figure 3). All items demonstrated high mean values, i.e., participants were in agreement with the statements. Solely the statement that NPIs should apply in 2022 demonstrated a tendency to the middle.

3.2.4. Observed Adverse Events following Immunization (AEFIs)

There was a weak significant association between experiencing AEFIs after the first inoculation and reporting a lower satisfaction with the process (Table 3). The data showed weak yet significant associations of increasing age and less frequent observation of pain at the injection site and onset of a known migraine within 24 h after the first vaccination. Regarding the second dose, there were more significant associations following the analogous path: pain at the injection site, fatigue, flu-like symptoms, headache, onset of known migraine within 24 h and circulatory weakness demonstrated to be significantly more often observed by younger participants.

3.3. Satisfaction of the Vaccination Centre Staff with the Process and Organisation of the Vaccination Campaign

Overall, 74 vaccination centre staff members participated in the survey, with 54 of them filling out the questionnaire in full (Table 1). Here, we also observed a high satisfaction rate.

The satisfaction of the staff was measured with seven items, where the majority presented a consistent mean above 4.50 (Figure 4). The item for information provision during induction was the only one with a lower mean value and a comparably broad standard deviation (4.28 ± 0.97935).

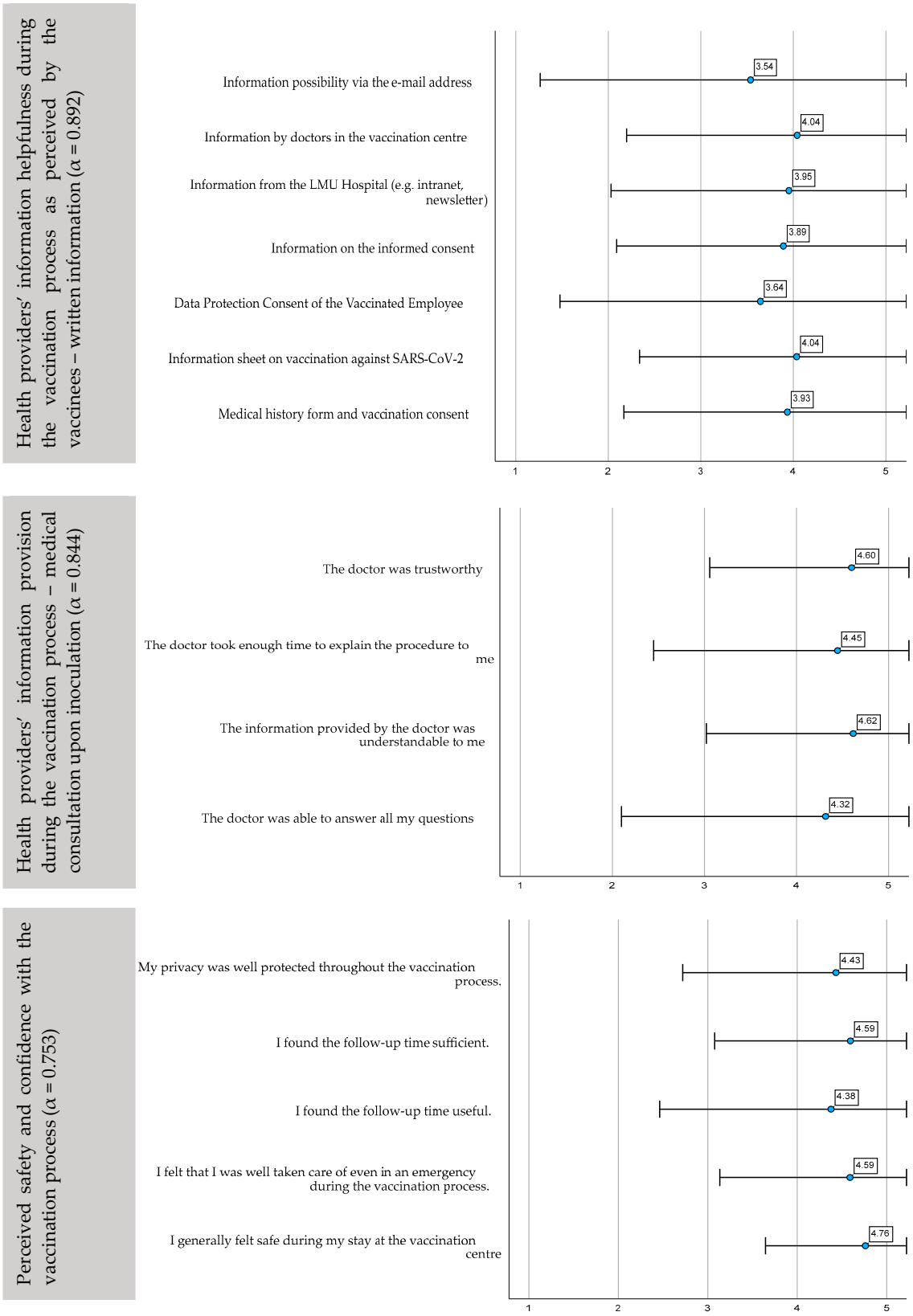

Figure 2. Individual and group influences: health providers' information quality and helpfulness during the vaccination process as perceived by the vaccinees—written information (α = 0.892), medical consultation upon inoculation (α = 0.844) and perceived safety and confidence with the vaccination process (α = 0.753). Mean values, standard deviation of the answers on the five-point Likert scale and Cronbach's Alpha.

Table 1. Sociodemographic and occupational data of surveyed HCWs vaccinated at the in-hospital centre as well as of surveyed vaccination centre staff. Potential factors were tested for association with satisfaction with a chi-square test.

	LMU University Hospital Staff Vaccinated at the In-Hospital Vaccination Centre					Vaccination Centre Staff °	
	n	**%**	**Satisfaction with Vaccination Process**	**AEFIs Following 1st Vaccine**	**AEFIs Following 2nd Vaccine**	***n***	**%**
Age *							
<29 years	188	14.2				4	7.4
30–39 years	297	22.5				9	16.7
40–59 years	269	20.3	$p < 0.001$	$p < 0.001$	$p < 0.001$	13	24.1
50–69 years	367	27.8				21	38.9
>60 years	189	14.3				7	13.0
No answer	12	0.9				0	-
Sex **							
Male	318	24.1	$p = 0.027$	$p < 0.001$	$p < 0.001$	20	37.0
Female	1001	75.7				34	63.0
Other	3	0.2				0	-
Education							
Secondary/elementary school	31	2.3				1	1.9
Middle school	198	15.0				7	13.0
High school/technical diploma	222	16.8				9	16.7
Vocational training	278	21.0	$p = 0.314$	$p = 0.219$	$p = 0.583$	2	3.7
Academic degree (bachelor)	94	7.1				1	1.9
Academic degree (master's/diploma)	203	15.4				4	7.4
Academic degree (doctorate or higher)	274	20.7				30	55.6
Other training	21	1.6				0	-
No diploma	1	0.1				0	-
Occupation (dichotomous) ***							
Medical staff	784	59.3	$p = 0.006$	$p = 0.012$	$p = 0.124$	31	57.4
Non-medical staff	538	40.7				23	42.6
Work with COVID-19 patients ****							
Yes	213	16.1	$p = 0.916$	$p = 0.123$	$p = 0.699$	53	98.1
No	1109	83.9				1	1.9
All	1322					54°	

* Age group distribution at LMU University Hospital: <29 years = 22.85%, 30–39 years = 29.11%, 40–59 years = 18.78%, 50–69 years = 20.89%, >60 years = 8.37%. The answer option "No answer" was excluded from the analysis as to not disturb the interpretation of the outcome. ** Sex distribution at LMU University Hospital: Female = 66.3%, Male = 33.7%. *** Occupational distribution at LMU University Hospital: Medical staff = 45.4%, non-medical staff = 54.6%. ° Of the 54 vaccination centre staff members, 47 had signed up voluntarily to support the centre and 7 had been assigned by their department heads; the 54 staff members had the following roles (multiple choice): admission and documentation ($n = 4$), preparation of the vaccination doses ($n = 13$), carrying out the inoculation ($n = 30$), follow-up of the vaccinated employees ($n = 3$), senior physician ($n = 12$), varying role ($n = 4$). **** Mean number of weeks = 23.25 (SD = 22.04, 1–60 weeks). The question was only available to fill out by participants who had selected "yes" to having had worked at a designated COVID-19 unit or with COVID-19 patients. Further, 22 participants answered that they had been working sporadically with COVID-19 patients. In addition to the mean number of weeks, there were

22 participants who reported to have occasionally worked with COVID-19 patients without providing a specific number of weeks. Of the vaccination centre staff, only 1 HCW had worked with COVID-19 patients for a total amount of 4 weeks.

Table 2. Frequency distribution of the satisfaction of LMU Hospital's employees with the vaccination centre and contextual influences and geographic barriers affecting the overall satisfaction with the vaccination centre tested with multinomial logistic regression (unadjusted model presented, °).

To What Extent Do You Agree with the following Statements? (In Absolute Numbers)					
General satisfaction $\alpha = 0.801$	Disagree	Rather disagree	Partly agree	Rather agree	Agree
The vaccination process at LMU Hospital was generally well organised.	12	10	64	222	1014
The registration and vaccination process were well organised.	15	27	83	239	958
The different stations in the vaccination centre were logically arranged.	7	8	17	175	1115
The vaccination appointment was easy to organise.	26	38	107	246	905
Satisfaction with the individual aspects of the vaccination process $\alpha = 0.808$	Disagree	Rather disagree	Partly agree	Rather agree	Agree
Prioritisation of departments to be vaccinated	16	82	203	517	504
Availability of the vaccine	28	160	409	400	325
Organisation of appointment booking	13	53	116	438	702
Scheduling of the administration of the second vaccination dose (availability of appointment options)	9	29	97	328	859
Process of registration at the vaccination centre	5	32	107	417	761
Possibility of a medical consultation at the vaccination centre	7	21	209	352	733
Preparation of the vaccine doses	4	6	222	278	812
Inoculation	5	7	37	266	1007
Follow-up after the inoculation	6	43	306	434	533
	The vaccination process at LMU Hospital was generally well organised. (item used for testing of general satisfaction)				
To what extent do you agree with the following statements?	Disagree/rather disagree		Partly agree		Rather agree/agree (ref.)
Location $\alpha = 0.164$ AIC = 77.531 BIC = 129.400	*n* (RR; *p*-value)		*n* (RR; *p*-value)		*n*
The vaccination centre at the LMU hospital was easily accessible in terms of location					
Disagree/Rather disagree	8 (9.542; 0.000)		11 (5.519; 0.000)		51
Partly agree	2 (1.478; 0.616)		7 (1.492; 0.339)		111
Rather agree/agree (ref.)	12		46		1074

Table 2. *Cont.*

To What Extent Do You Agree with the following Statements? (In Absolute Numbers)			
Even if it had taken me over 1 h to get there to receive the vaccine, I would still have taken the time to get there.			
Disagree/rather disagree	7 (9.502; 0.000)	0	38
Partly agree	1 (1.568; 0.669)	5 (1.775; 0.241)	58
Rather agree/agree (ref.)	14	59	1140
Waiting time * $\alpha = 0.706$AIC = 94.242 BIC = 166.699	Disagree/rather disagree	Partly agree	Rather agree/agree (ref.)
How long was the waiting time from registration at the vaccination centre until you received the inoculation?	*n* (RR; *p*-value)	*n* (RR; *p*-value)	*n*
Less than 10 min	5 (0.027; 0.000)	34 (0.565; 0.473)	696
Between 10 and 20 min	8 (0.100; 0.006)	20 (0.453; 0.315)	437
Between 20 and 30 min	2 (0.234; 0.112)	6 (0.991; 0.991)	65
Over 30 min (ref.)	6	3	29
I cannot remember	1	1	9
How much time did you spend at the LMU Hospital vaccination centre in total?			
Less than 30 min	8 (0.846; 0.856)	23 (0.507; 0.411)	570
Between 30 and 45 min	7 (0.427; 0.331)	32 (0.806; 0.785)	520
Between 45 and 60 min	1 (0.107; 0.054)	6 (0.437; 0.316)	119
Over 1 h (ref.)	5	3	23
I cannot remember	1	0	4

* For the purposes of this analysis the answer option "I cannot remember" was removed as to not disrupt the statistics. The confidence intervals were removed for better readability.
° Multinomial logistic regression model. The models adjusted for age, sex and occupation did not present a significant association with the satisfaction and were therefore not preferred for the further analyses performed.

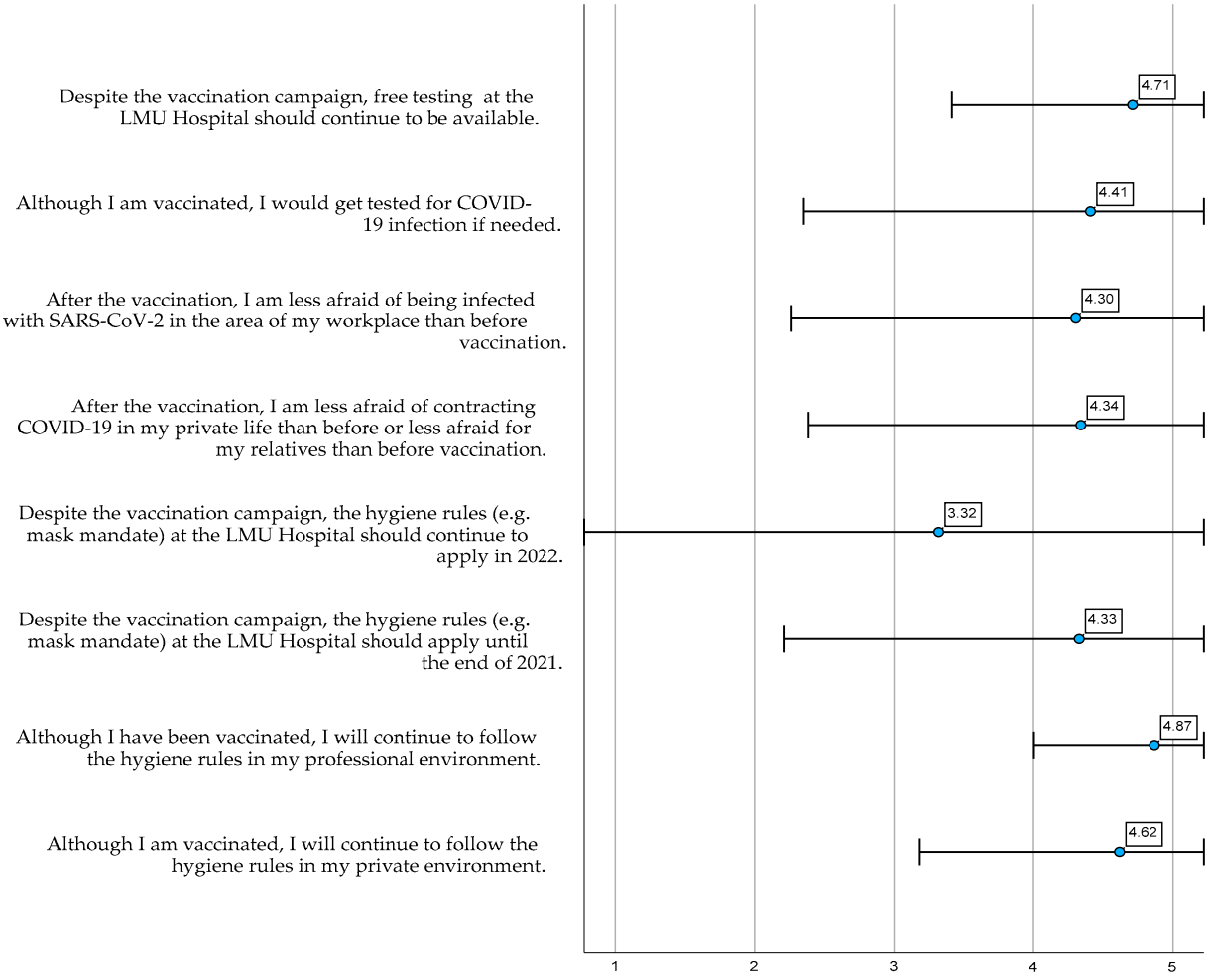

Figure 3. Attitudes and attitude changes towards COVID-19 non-pharmaceutical interventions ($\alpha = 0.687$). Mean values, standard deviation of the answers on the five-point Likert scale and Cronbach's Alpha.

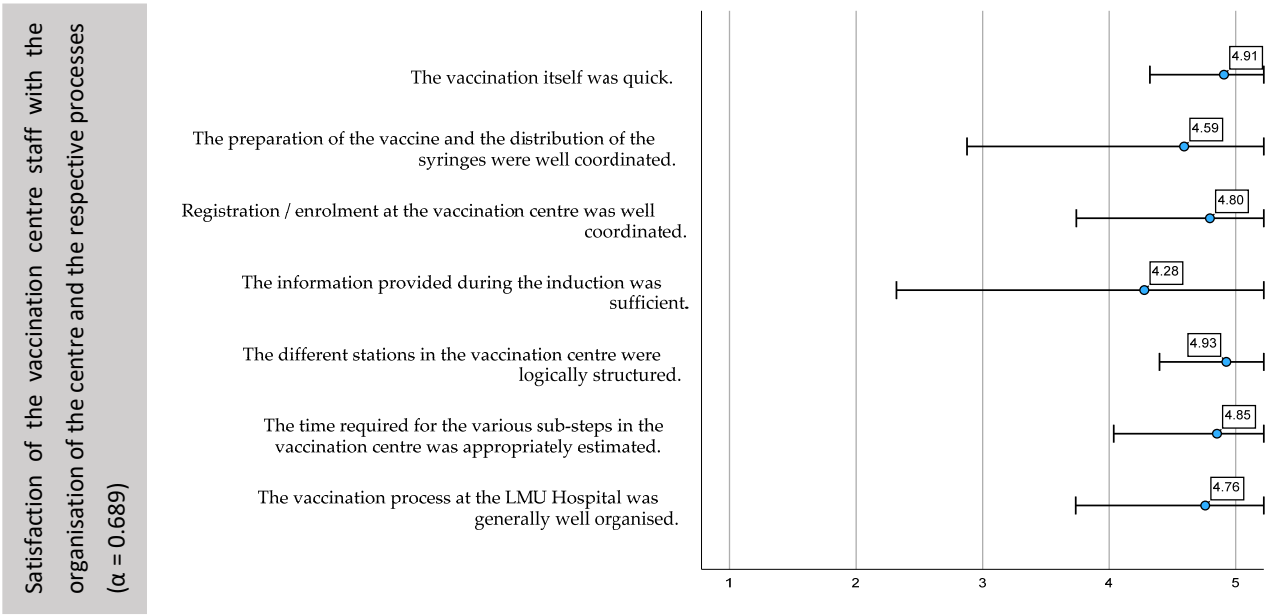

Figure 4. *Cont.*

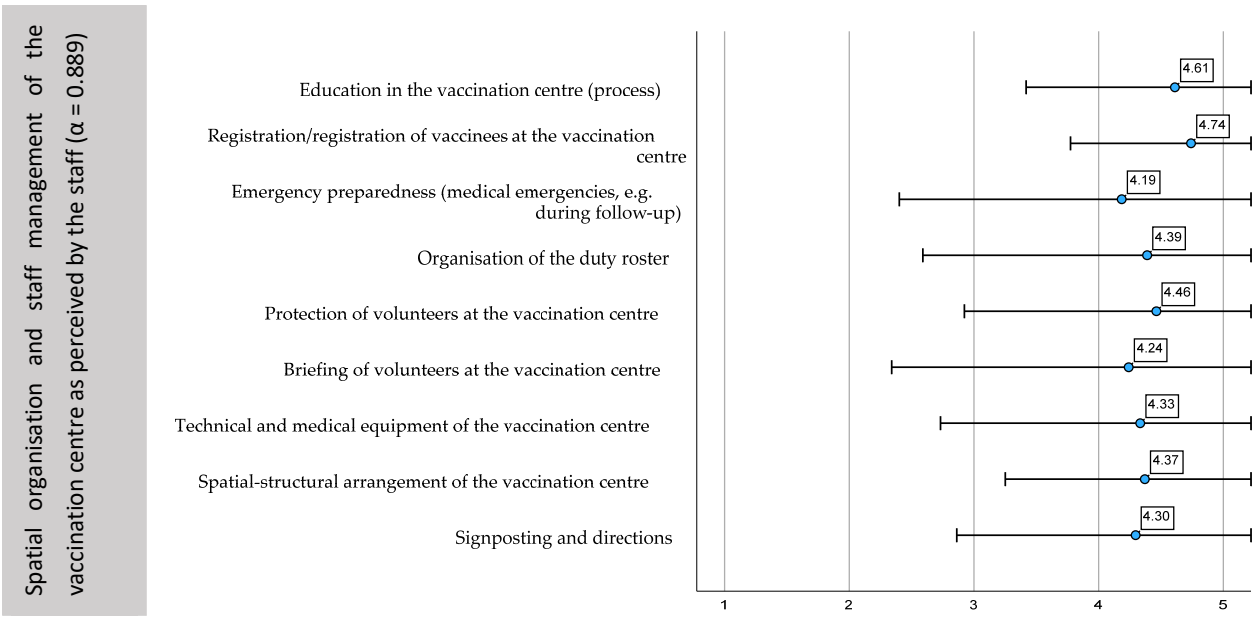

Figure 4. Satisfaction of the vaccination centre staff with the overall organisation of the centre, including spatial-structural layout. Mean values, standard deviation of the answers on the five-point Likert scale and Cronbach's Alpha.

Similarly, the nine items for spatial arrangement and staff management demonstrated comparable consistency, with all items presenting mean values above 4.0 (Figure 4). The lowest mean value referred to the individual's perception of preparedness in emergency cases (4.19 ± 0.89177).

The eight items on the quality and helpfulness of the information delivered throughout the process also demonstrated consistent mean values above 4.0 (Figure 5). The item with the lowest mean value and broadest standard deviation referred to the written form on data consent (4.07 ± 1.00662).

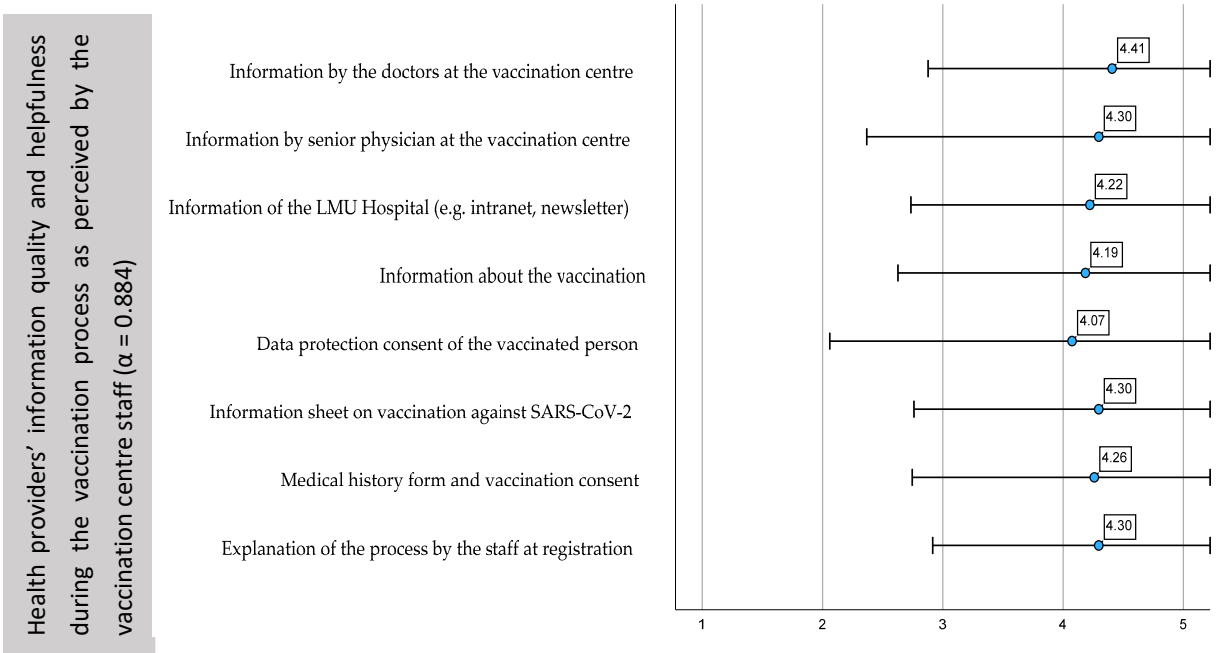

Figure 5. *Cont.*

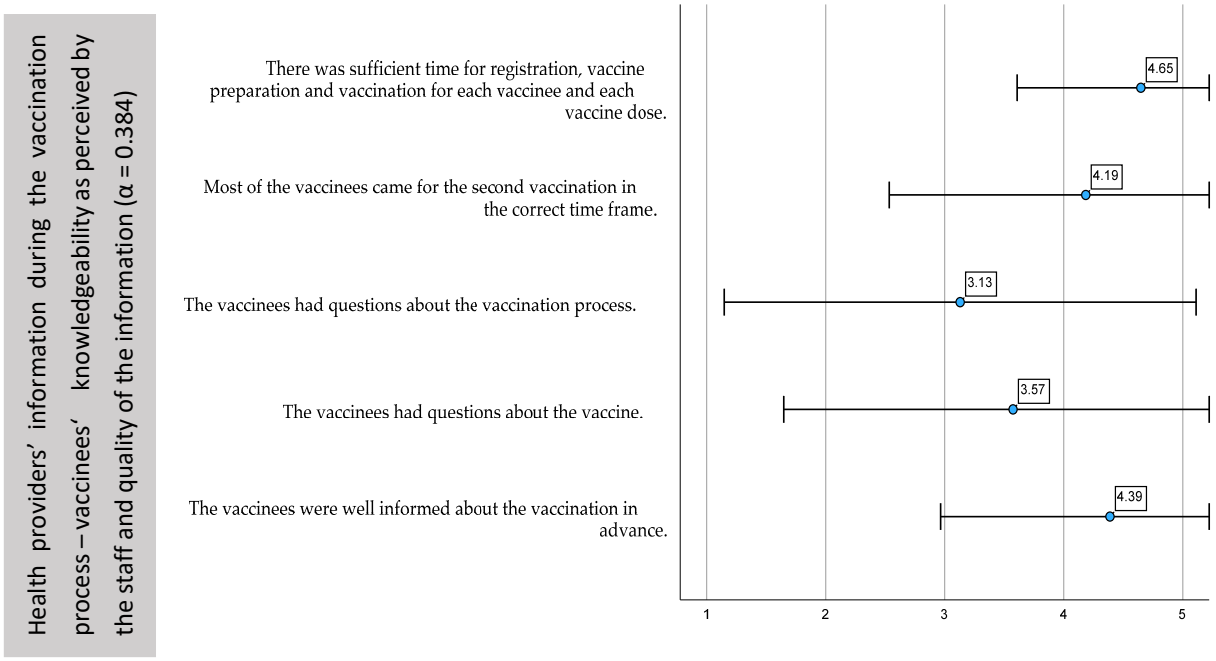

Figure 5. Perception of the vaccination centre staff of the information provision prior to inoculation. Mean values, standard deviation of the answers on the five-point Likert scale and Cronbach's Alpha.

Further, we asked staff members about their perception of the vaccinees' knowledgeability regarding COVID-19 vaccines (Figure 5). The five items demonstrated low internal reliability, where the item with the lowest mean value on the Likert scale referred to the perception if vaccinees had questions about the vaccine process prior to inoculation (3.13 ± 0.99140).

The 10 items for satisfaction with the working atmosphere showed consistent mean values (Figure 6). Only the two items comparing the workload at the vaccination centre with that in the regular jobs of staff members demonstrated particularly low mean values, indicating that the workload was neither lower nor higher than that at the regular workplace of staff members (3.56 ± 1.26888, respectively, 2.1852 ± 1.06530).

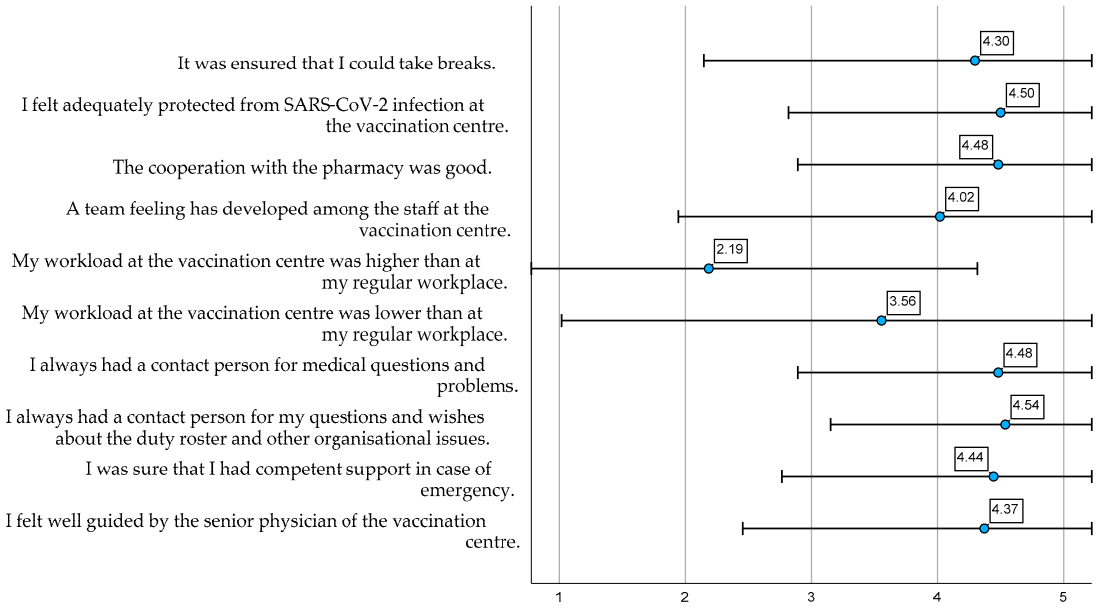

Figure 6. Satisfaction with the working atmosphere at the vaccination centre ($\alpha = 0.705$). Mean values, standard deviation of the answers on the five-point Likert scale and Cronbach's Alpha.

Table 3. Adverse events following immunization observed and reported by vaccinees.

Effect of the Observation of AEFIs on the General Satisfaction [+]							**RR, *p*-Value**		
Did you observe any adverse reactions after the first vaccination dose?—Yes (n = 676)							−0.479, 0.001		
Did you observe any adverse reactions after the second vaccination dose?—Yes (n = 924)							−0.052, 0.745		
AEFIs following 1st Vaccine * n = 687	Intensity of adverse reaction						Age °	Sex ** °°	Occupation (med vs. non-med) °°
	n	Not at all	Very mild	Mild	Strong	Very strong	Kendall Tau p-value	Cramér's V p-value	Cramér's V p-value
Pain at the injection site	591	21	96	185	186	103	−0.090 p = 0.004	0.153 p = 0.008	0.099 p = 0.212
Redness	571	415	91	44	14	7	−0.008 p = 0.413	p = 0.178 °	p = 0.163 °
Haematoma	566	509	25	16	12	4	−0.010 p = 0.393	p = 0.377 °	p = 0.689 °
Fatigue	581	193	103	115	91	79	0.013 p = 0.347	0.130 p = 0.044	0.113 p = 0.115
Flu-like symptoms (e.g., aching limbs, chills)	568	392	74	42	25	35	0.021 p = 0.283	0.088 p = 0.357	0.039 p = 0.933
Headache	578	331	79	73	48	47	−0.046 p = 0.094	0.105 p = 0.179	p = 0.540
Known migraine (triggering of an attack within 24 h)	561	533	7	7	4	10	−0.069 p = 0.035	p = 1.000 °	p = 0.878 °
Known tension headache (triggering an attack within 24 h)	556	521	13	8	5	9	−0.015 p = 0.350	p = 0.297 °	p = 0.367 °
Dizziness/balance problems	568	468	45	29	15	11	0.026 p = 0.244	p = 0.168 °	0.123 p = 0.071
Circulatory weakness	567	496	35	18	10	8	−0.033 p = 0.192	p = 0.246 °	p = 0.949 °
Fever $\geq$ 38 °C	568	518	21	11	8	10	−0.038 p = 0.153	p = 0.060	p = 0.065 °
Nausea, vomiting	569	523	22	14	5	5	0.058 p = 0.063	p = 0.511 °	p = 0.877 °
Diarrhoea	563	525	23	6	6	3	0.056 p = 0.068	p = 0.789 °	p = 0.501 °

Table 3. *Cont.*

Effect of the Observation of AEFIs on the General Satisfaction [+]							RR, *p*-Value		
AEFIs following 2nd Vaccine * n = 935	n	Not at all	Very mild	Mild	Strong	Very strong	Age	Sex ** °	-
Pain at the injection site	827	64	217	255	170	121	−0.155 $p < 0.001$	0.142 $p = 0.002$	-
Redness	795	595	115	52	15	18	0.011 $p = 0.361$	$p = 0.137$ °	-
Haematoma	786	714	37	16	11	9	−0.014 $p = 0.326$	$p = 0.018$ °	-
Fatigue	820	97	87	175	216	246	−0.054 $p = 0.029$	0.129 $p = 0.009$	-
Flu-like symptoms (e.g., aching limbs, chills)	796	269	103	103	133	189	−0.090 $p = 0.001$	0.131 $p = 0.009$	-
Headache	807	287	117	141	127	135	−0.091 $p = 0.001$	0.192 $p < 0.001$	-
Known migraine (triggering of an attack within 24 h)	764	710	11	7	14	22	−0.065 $p = 0.022$	$p = 0.629$ °	-
Known tension headache (triggering an attack within 24 h)	769	670	20	14	35	30	0.002 $p = 0.477$	$p = 0.018$ °	-
Dizziness/balance problems	792	582	71	55	51	33	−0.047 $p = 0.064$	0.147 $p = 0.002$	-
Circulatory weakness	781	600	76	50	38	18	−0.050 $p = 0.055$	0.133 $p = 0.008$	-
Fever $\geq$ 38 °C	778	538	54	57	58	71	−0.064 $p = 0.018$	0.078 $p = 0.312$	-
Nausea, vomiting	794	671	47	35	25	16	0.032 $p = 0.150$	$p = 0.004$ °	-
Diarrhoea	781	705	28	24	14	10	0.035 $p = 0.134$	$p = 0.448$ °	-

[+] Ordinal regression for an association between AEFIs after the first and second vaccination dose and the general satisfaction with the process. The unadjusted model was preferred for interpretation because in the model adjusted for age, sex and occupation 52.1% of the cells were with zero frequencies. The reference group for both items is "No". * Excluded from the analysis are adverse events that were additionally added by participants under the category "others". After the first vaccine, 85 participants reported experiencing "other" AEFIs; after the second vaccine, the reports of "other" adverse events were 143. ** For the purposes of this analysis, we have excluded the item "other" (n = 3) as it would not permit the execution of the test. n = 1319 ($N_{missing}$ = 3). ° Kendall Tau correlation test. °° Chi-square test (Cramér's V coefficient). For sex and occupation, the Fisher's exact test p-value is reported where the expected cell count of 20% or more of the cells is lower than 5.

4. Discussion

To our knowledge, this paper provides the first published insights into the organisation and evaluation of a large-scale in-hospital vaccination centre in Germany on the basis of the experience gathered through implementing and operating a COVID-19 vaccination campaign for 11,005 HCWs.

4.1. Organisation of the Vaccination Centre—Implementation Considerations

The currently available literature concerned with the topic of organising a COVID-19 vaccination centre is still narrow and mainly concerned with mass vaccination sites for the general population [16–18]. As there is a rather limited body of evidence specifically on the organisation of COVID-19 large-scale or mass vaccination centres in hospitals, and specifically for HCWs, our results allow only for a narrow contextual observation.

The number of vaccine doses inoculated in the centre every day corresponds to the rate in the COVID-19 hospital-based or mass vaccination sites [16,19,20]. It should, however, be noted that our centre operated, even in its initial phase, with a rather limited number of personnel for the inoculations compared to the centres described in the literature so far. This is ascribed to the strictly defined dimension of the target group (HCWs vs. population-wide) as well as to the zero-sum nature of the centre's roster management with physicians consequently being unavailable to provide health care for patients when assigned to the vaccination centre. However, the time needed per vaccinee as well as the time that vaccinees spent in the centre on average compares to the indicators of population-wide COVID-19 and non-COVID-19 mass vaccination sites [16,20]. It is noteworthy that the vaccination centre described deployed a larger number of physicians as vaccination staff compared to public vaccination centres with a larger proportion of nursing staff or medical assistants. This reflects the staff structure of a university hospital. Nevertheless, this instance might have influenced the satisfaction of the HCWs with the vaccination process.

Further considering personnel management, planning and scheduling staff on a voluntary basis assumes a certain degree of predictability and neglects motivation loss over time, as observed at the beginning of the first campaign. We therefore recommend the later adopted option of a planned roster, as this allows for better reliability. Additionally, the arrival of vaccinees at specific times of the day should lead to further adjustments in the personnel planning in the future, in order to cover the bottleneck timeslots more efficiently. Further, as other case studies have pointed out, an onsite manager who continuously monitors and, as appropriate, adapts the workflow, is highly beneficial to the agile management required in the setting [19].

The lessons learned during the first vaccination campaign, especially concerning personnel, facilitated the setup of the second vaccination phase (October–December 2021), to the extent that we were able to offer a mean of 17 influenza shots/hour (range: 3–32 shots), in addition to COVID-19 inoculations, without staff changes. However, no-show rates rose rapidly, to almost 16% (no extra-shows), likely reflecting several factors specific to the second vaccination campaign: as this period coincided with a sharp rise in SARS-CoV-2 incidence, it is possible that many HCWs had to delay their scheduled vaccination due to an infection [21]; further, this period encompassed several adaptations of the vaccination recommendations that might have interfered with one's eligibility or motivation for receiving a vaccine [22]; lastly, the prioritisation of vaccinations was lifted at the end of the first vaccination campaign, which may have influenced the accessibility to appointments in other vaccination centres preferred by the hospital's employees due to their temporal or geographical convenience compared to the in-hospital centre [23].

4.2. Satisfaction with the Vaccination Process

Our findings indicate a direct association between the accessibility of a vaccine and the satisfaction with the vaccination process. Especially regarding geographical barriers, the results emphasise the need to improve access and reduce physical impediments even among vaccine-receptive populations. Although the Vaccine Hesitancy Matrix observes

the contextual influences independently from the vaccination-specific issues, our findings accentuate the benefit of considering those simultaneously, as geographical and temporal barriers may serve as guidance in the design of vaccination programmes [13]. Admitting the possibility of debate on convenience as a factor in hesitancy models, its effect on the satisfaction with the process and, potentially, future willingness to vaccinate, needs to be addressed in order to increase vaccine uptake, even when the respective campaign is organised at the workplace [24–26]. This is a particularly relevant aspect in the context of our centre's organisation, as many HCWs working outside the main campus had to plan for additional travelling time to and from the vaccination centre. Even if our results show that the large majority of HCWs were willing to travel longer than 1 h to receive their inoculation(s), this outcome should only be considered in the context of limited access to vaccines outside of the hospital's centre during this period of time in the population-wide vaccination campaign. This especially concerns employee groups that were scheduled for vaccination later on in the campaign, e.g., HCWs without direct patient contact, in administrative or other non-medical positions. Furthermore, the observed association between accessibility and satisfaction indicates a potential issue of providing vaccinations in a single centralised centre rather than in a decentralised form covering all locations of the hospital. Looking ahead, and specifically for settings similar to the LMU University hospital, it would be advisable to systematically explore the advantages and disadvantages of a centralised vs. decentralised vaccination supply including the preferences of HCWs. The factors affecting the satisfaction with the COVID-19 vaccination centre can serve as a reference in these future analyses.

In a similar manner, there is a need for consideration of the experience of AEFIs as a factor potentially influencing COVID-19 vaccine-related decisions in the future, as vaccine adaptation and emerging variants of concern may pose the need for further COVID-19 large-scale and mass vaccination campaigns [27]. The factors affecting the satisfaction with the vaccination process indicated by our results need to be taken into account in subsequent research attempts, as these may generally alter the circumstances and arguments in future vaccine-related decision-making processes by HCWs [12]. Specifically, further examination should be focused on whether the AEFI-related experience after a COVID-19 vaccination could affect any future decisions on receiving another COVID-19 inoculation but also vaccinations against other infectious diseases. This constitutes a crucial topic for research, in view of the HCWs' influential gatekeeping role for vaccine uptake in the general population, e.g., via provider-based interventions [28–30]. Additionally, our results show that the AEFI experience following an inoculation significantly affects the satisfaction with the setting where the inoculation has taken place. This potential confounder should be accounted for in future evaluations of vaccination programs and campaigns. The frequency and distribution of AEFIs reported by participants in our survey are consistent with previously reported data in a comparable setting and population [31].

In terms of COVID-19 behaviour, our results present referential data to the first questionnaire of the IMPF^{LMU} project which examined this topic several months prior to the surveys presented here. The overall adherence to the extension of NPI at the hospital confirms the data from the first questionnaire that showed an association between a positive vaccination status and rather agreeing to the extension of the NPIs validity beyond 2021 incl. PCR testing [6]. However, although this aspect was not explicitly examined in the survey, a shift in the attitude towards not extending NPIs' validity may be hypothesised. This is especially to be considered against the background of the surveys presented here taking place several weeks after the first survey on vaccine hesitancy. Additionally, the questionnaires presented here were available to the target groups in a time period with a higher rate of fully vaccinated HCWs at the LMU University hospital and a lower incidence of SARS-CoV-2 in the general population; hence, participants may have considered the vaccination against COVID-19 as a sufficient preventive measure in the future as well [21].

Further, the results presented here underline the outcomes of the first questionnaire stating that HCWs with a positive vaccination status are less worried about getting infected with SARS-CoV-2 in their personal or professional environment [6].

The overall satisfaction of the vaccination centre staff and the perception of the workload as neither lower nor higher than usual testify to the fidelity of the implementation. Similar to the report of De Micco et al., our results indicate a strong sense of team spirit and commitment by the centre's staff, hence underlining the role of leadership and personnel management beyond the formative fulfilment of the required tasks [19]. This aspect is particularly crucial for consideration upon implementing a human resource strategy based on planned duty roster, as Hrehova et al. report a relatively higher incidence of self-reported burnout symptoms among HCWs assigned to work at a mass vaccination centre as part of their regular jobs rather than voluntarily [32].

4.3. Limitations

Several limitations need to be considered when interpreting the results of this work.

It is uncertain whether the described personnel management can be transferred to other hospitals or settings, especially regarding the number of physicians instead of medical assistants or nursing staff involved, which rather reflects the staff structure of a university hospital than the requirements of vaccination centres. Still, our results provide an indication of the human resources needed for a large-scale vaccination centre, where the majority of the roles may also be assigned to other HCWs with similar qualifications to perform the given tasks, e.g., planning for five qualified medical assistants instead of five physicians to execute the inoculations.

In terms of administrative support, it should be noted that due to the rapid setup, the initial email inquiries were only partially saved, hence we can only provide a general assessment of number and content rather than a detailed analysis.

Both surveys were available to the target groups for approx. 2 months, thus not covering the complete period of the vaccination campaign. Changes in attitude towards COVID-19 vaccines could have potentially been driven by newly distributed information, adaptations of the recommended vaccination scheme, prioritisation or other factors but were not considered in the survey design. Further, the consistently high uniformity of answers to a majority of the questions did not allow for a meaningful and powerful inferential analysis, hence reducing the evaluation to a rather descriptive report. In terms of design it should be noted that the high satisfaction reported by participants may in part be due to an acquiescence bias despite the specific definition of the middle-point in the Likert scale to every item, or other response biases [33]. Further, although our results reflect the evidence on AEFI observation and age, other potentially related factors were beyond the framework of this analysis [34]. Additionally, we need to note the limited response to the survey for vaccinees. As this was the second survey of the IMPF^{LMU} project, it can be hypothesised that the weaker response could be partially owing to a depleted motivation of HCWs to participate in COVID-19 vaccination surveys. To a certain extent, this hypothesis could be broadened to include a general exhaustion with the topic, since COVID-19 was the predominant issue at the LMU University Hospital and beyond during the period of the survey. Further, the voluntary design of the survey certainly accounts for low participation. We acknowledge that a different or an addition dissemination approach might have facilitated the participation in both surveys: an example of such a strategy would have been to promote the surveys on site using posters presenting a QR code and/or link to both surveys.

In terms of representativeness, the age and sex distribution of participants in the survey for vaccinees is similar to the distribution in the whole target population, thus making the results fairly representative for the HCWs inoculated at the in-hospital vaccination centre.

As a long-term observation was outside of the scope of this evaluation, the displayed outcome lacks information on potential fluctuations of the perception of the vaccination centre and process. That is to be considered against the background of limited vaccine

availability at the beginning of the campaign and gradually increasing availability subsequently. However, we feel that a follow-up data collection would not have been meaningful due to the fast-paced changes in recommended inoculated vaccines as well in the general pandemic situation that may have implied further confounding factors which one could have not accounted for.

Nevertheless, our work presents valuable insights into the specifics of organising and managing a large-scale in-hospital vaccination centre. As other studies have showed, HCW vaccination campaigns require a tailored yet accessible and agile approach in order to facilitate the uptake of vaccines [35]. A German-wide analysis of in-hospital COVID-19 vaccination has previously highlighted the accessibility to appointments as well as communication as particularly important aspects in designing a vaccination campaign among hospital-based HCWs [36,37]. The comprehensive description of the hospital's centre as well as the outcomes of its evaluation provide important guidance towards planning, implementing and assessing similar campaigns in comparable settings and contexts.

5. Conclusions

Implementing and managing a large-scale in-hospital vaccination campaign requires a specific focus on the geographical and temporal accessibility of the vaccination centre. An agile personnel management is necessary both in terms of the centre staff as well as on the hospital-wide level, as demands may rapidly change and AEFIs may noticeably affect the working ability of vaccinated HCWs, which may, in turn, affect the provision of care to patients. The potential effect of self-reported AEFI experiences following a COVID-19 vaccination on future decisions on vaccination uptake may represent a particularly relevant topic for research. Additionally, self-reported AEFIs following inoculation need to be considered as a confounding variable in the evaluation of the satisfaction with vaccination campaigns and programs, as these appear to significantly affect the perception of the setting where the respective inoculation has taken place. Regardless of the high effectiveness of vaccinations, campaigns among HCWs should still aim to facilitate the adherence to non-pharmaceutical preventive measures such as wearing a mask, testing regularly, and other personal hygiene standards. This is a crucial factor to be considered in occupational health promotion, as our results underline the need for a strategically selected and tactically implemented set of measures that facilitate the achievement of a paramount goal rather than observing and evaluating a single measure. Future research should aim to examine health promotion campaigns in occupational settings as a whole and observe potential interactive and inversely proportional coherences between the adherences to different health promotional activities.

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Informed Consent Statement: Informed consent was obtained by all participants in an electronic form. Filling out the questionnaire was possible only after agreeing to the data usage notice approved by the Data Protection Officer of the LMU University Hospital.

Data Availability Statement: The presented survey data in this study are available on request from the corresponding author. The data are not publicly available due to the data protection policy of the LMU University Hospital.

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