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Uncertainties beyond preparedness: COVID-19 vaccination in Senegal

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Abstract
Vaccination is one of the most recognised strategies in public health for preventing the spread of epidemics, and the availability of a vaccine is often expected by health actors to be a 'game-changer'. However, the COVID-19 (coronavirus disease 2019) vaccine in Senegal was not the magic bullet that the international community expected. A very low vaccination coverage rate (less than 10% by April 2023) was observed in this country, once considered a model in West Africa for its epidemic response. Beyond the population's alleged hesitancy to be vaccinated, was a lack of preparedness to blame? Previous analyses show that outbreak preparation limited to standard interventions is not sufficient in the face of the social, cultural, and political configurations of each epidemic context and that uncertainty limits response capacity. This paper examines the social life of the COVID-19 vaccine to identify the forms and contextual dimensions of uncertainty related to immunisation in Senegal. The authors explore how vaccination was implemented and compare experiences with the preparedness process, to offer insight on uncertainties. Using Stirling's theoretical model that defines various expressions of incertitude, the authors identify four nexuses at various stages of the social life of COVID-19 vaccine in Senegal: (1) material uncertainty related to vaccine availability, (2) ambiguity of the population about the purpose of vaccination and the risks of the disease, (3) uncertainty related to side effects, and (4) uncertainty about vaccination strategies shared by scientific and health authorities. These uncertainties were only partly considered in the preparedness process, for they are related to systemic structural dimensions and reflect the impact of global/regional powers on the local level. The findings of this research are relevant not only to support better communication around vaccines in Senegal but also more generally to the prevention of emerging epidemics shaped by human behaviours.

Introduction

Global COVID-19 response and the vaccine gap in Africa

In 2021, the World Health Organization (WHO) set one of the most ambitious public health targets in history a 70% coronavirus disease 2019 (COVID-19) vaccination rate in all countries by mid-2022. This goal was based on both an epidemiological rationale (reducing the circulation of the virus through herd immunity) and a human rights rationale (reaching equity in access to immunisation), summed up in the oft-repeated words of Dr Tedros Adhanom Ghebreyesus: 'No one is safe until everyone is safe' (WHO, 2020a). This ambitious target aimed to reduce individual vulnerability to disease and death and limit the risk of the emergence of viral variants through the vaccination of nearly 6 billion people worldwide, regardless of contexts or structural inequalities.

It was also ambitious in that it was planned to be global and synchronous across all continents from the outset, whereas in the past, most of the vaccines used in populations based in low-income countries (LICs) were not made available until years or decades after their use in high-income countries (HICs) (Moulin, 1996). Finally, it was ambitious in targeting the general population, including adults who do not regularly attend health services.

Two years later, UNDP's Global Dashboard for Vaccine Equity showed mixed interim results: vaccination had remained largely the preserve of HICs. Although there were enough vaccines to supply 95% of the world's population, the 70% target had not been met by 27 LICs (United Nations Development Programme, 2022). At the beginning of 2023, the gap between HICs and LICs in terms of immunisation coverage remained very large, particularly in sub-Saharan Africa (home to 33 out of 39 LICs). On 5 February 2023, the rate of people fully vaccinated in Africa was less than 30%, half of the global rate (28.45% vs. 63.84%) (Our World in Data, 2023), with major differences between countries (Liberia had exceeded 70% coverage rate by the end of 2022, while the DRC rate was under 7%).

This gap is particularly striking when one considers the credit given to the vaccine by the global health community in epidemic response, especially in low- and middle-income countries (LMICs), where the vaccine is considered one of the most cost-effective public health interventions (Utami *et al.*, 2022). The global evaluation of the response to the COVID-19 pandemic showed that vaccination against severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) was effective in reducing case fatality, particularly in those vulnerable due to age and/or comorbidities, and in reducing human-to-human transmission and circulation of the virus, that is, end the pandemic (Sachs *et al.*, 2022). The international media reported two main causes for the coverage gap in Africa: insufficient access to the vaccine, which had been cornered by rich countries in the absence of vaccine production capacity on the continent, and population hesitancy. Could vaccination have been better prepared?

Pandemic and vaccine preparedness applied to COVID-19

In the reference texts on pandemic preparedness, vaccination is listed among 'pharmaceutical measures' of epidemic response, along with medication, diagnostics, and medical equipment. The importance of supporting research and rapid development of vaccines is emphasised, as well as stockpiling of vaccines, with conditions to ensure the cold chain (WHO, 2017). Within WHO Framework for Emergency Preparedness 2017 (WHO, 2017), global preparedness is informed by risk assessment and prediction using metrics and statistic modelling and implemented across governance, capacity, and resources. Preparedness is also considered as response strengthening, that is, reducing risk through measures with evidence-based benefits in an iterative cycle of planning, implementation, evaluation, and updating (Leach *et al.*, 2022a).

While preparation has long been considered as an activity developed between outbreaks, aimed at preparing for hypothetical future events (Lakoff, 2017), the experience of the COVID-19 pandemic challenged this temporality. Due to the magnitude and duration of the pandemic experienced locally through 'epidemic waves', rather than a single preparedness process tailored to a local outbreak, preparation in practice became entangled with response in a series of parallel processes attached to strategic 'pillars' as defined by WHO (WHO, Regional Office for Africa, 2021). WHO and other global health agencies have referred to this process as 'Sailing the boat while building it', as was already the case in the response to the human immunodeficiency virus (HIV) epidemic in the 1990s. This idiom emphasises the imperative to not delay interventions despite the context of uncertainty that is the framework of constraints for policymakers in times of crisis (Parviainen *et al.*, 2021).

Uncertainty and vaccination

This article explores the gap between preparedness and results in vaccine coverage based on the differences between practices and discourses about 'what was prepared' and 'what happened' in

the varied social contexts where the vaccine was managed, focusing on Senegal. The authors use Appadurai's 'social life of things' model that considers material objects (such as medications) as embedded within nexuses of social relations (Appadurai, 1988). This conceptual approach has been applied widely to study the circulation of pharmaceuticals, especially in LMICs (Reynolds Whyte *et al.*, 2002; Desclaux and Egrot, 2015). The concept 'nexus' conveys the idea that at every stage of a vaccine's social life, a category of actors, a form of knowledge, and a material environment are concerned. Another key concept is needed in an epidemic crisis when scientific knowledge is limited regarding an unknown pathogen, the conditions for its emergence, the risks and outcomes attached to its transmission, and the means for diagnosis and control. 'Incertitude', as defined by Stirling (1999), covers the lack of knowledge on risk and outcomes ('ignorance') and the lack of knowledge about outcomes and their likelihood ('uncertainty'). For Stirling, incertitude also refers to doubts and interpretations contested between actors ('ambiguity') with a subjective (individual or collective) relation to knowing or not knowing. The relationship between preparedness and incertitude is complex: global health considers that achieving readiness should reduce uncertainties for those involved. From their analysis of the management of the Ebola, Nipah, cholera, and COVID-19 epidemics, Leach *et al.* (2022a) conclude that recognition of knowledge practices to manage the incertitude is necessary to complement risk-based epidemiological models, as epidemics evolve unpredictably. They describe how everyday experiences of risk, uncertainty, ignorance, and ambiguity, as well as locally situated knowledge practices, are often excluded from preparedness plans and should be taken into account. Following ignorance studies that reveal the wide scope and the social effects of 'not knowing' (Gross and McGoey, 2022), Paul and Haddad capture the role of ignorance as a constitutive feature of policymaking at various stages of COVID-19 response (Paul and Haddad, 2023).

In this article, after presenting an analysis of the preparedness policy and process for making Senegal ready for vaccination, the authors analyse the implementation of the COVID-19 vaccination strategy through four 'nexuses of uncertainty' which hindered the expansion of vaccination coverage, as identified by their grounded approach. For each nexus, the authors explore the contextual barriers to vaccination, describe their social effects, and then make explicit the role of uncertainties (beyond the epidemiological dynamics) experienced by a community of actors. Finally, the authors discuss the forms of uncertainty engaged in the nexuses and the global/ regional drivers at stake, along this social life of vaccines.

Their aim is not to identify all the factors behind low immunisation coverage rates nor to point out failures in the national response or responsibilities in preparedness but to understand the entanglement between several forms of knowledge/uncertainty and their consequences. This analysis of uncertainty and its social embeddedness in vaccination may assist in the adaptation of immunisation to protect the Senegalese population from COVID-19 infection, then the global population, and to help society recover and prepare for future epidemics.

Context

Senegal was chosen for this analysis as it was among the three countries with the lowest COVID-19 vaccination rates in Africa at the beginning of 2023, with only 8.27% of the population having completed their primary vaccination by 5 February (Foreign Policy, 2020). Paradoxically, this country was also recognised as one of the best prepared to deal with epidemics on the continent, particularly because of the health emergency operations centre that was established following the Ebola epidemic with organisational, material, and human resources that provide expertise to other African countries. In August 2020, Senegal obtained the second-best score, following New Zealand, out of 36 countries for the COVID-19 Global Response Index delivered by Foreign Policy (2020). Highlighted by some international media as a model for COVID-19 response, it was chosen in 2021 for the production of COVID-19 vaccines.

The first case of COVID-19 in Senegal was reported on 2 March 2020, 2 days after Nigeria identified the very first case in West Africa (Dia *et al.*, 2020). By the end of 2022, 88,910 cases and 1,971 deaths had been confirmed in the country. For an estimated population of 17.7 million, this represented 5,134 cases per million (less than Africa as a whole with 8,769 per million) and a case fatality rate of about 2%. By the beginning of 2023, Senegal had been hit by five epidemic waves, almost simultaneously as most countries in Africa in terms of the rate of confirmed cases in relation to the population, with the highest peak in the third wave due to the Delta variant (June to August 2021). The national response to COVID-19 was based on a set of interventions including public health measures for several months such as a state of emergency, border closures, curfews, and restrictions on meetings, markets, and transport, with a strong impact on the economy, especially in the informal sector (Ridde and Faye, 2021); these stringent measures are seen as having assisted in health system resilience (Bousso *et al.*, 2022).

Methods

This study was conducted as a part of the Pandemic Preparedness Project (PPP), a multi-sited social science research that focused on how preparedness is interpreted in ideas and practices at global, regional, and national levels in Senegal, Sierra Leone, and Uganda. The findings presented in this article are based on an analysis of data collected during PPP in combination with data from two other studies in Senegal: one on community mobilisation and socio-sanitary issues (CORAFMOB) and another on the globalisation of information and the social construction of COVID-19 response perceptions (CORAFSEN) (Desclaux, 2020). All three qualitative studies collected data through interviews, document reviews, and ethnographic observation.

Data collection for PPP began in 2019, allowing the authors to meet with 21 key informants involved in preparedness programmes at the regional (Africa, West Africa, and West and Central Africa) and the national (Senegal, Guinea) levels prior to the emergence of COVID-19. This first set of recorded exploratory interviews mapped the institutions concerned by pandemic preparedness; described their policies, roles, and practices; and finally identified their approaches to epidemic risk and preparedness for a hypothetical infectious threat. Additional data were collected through participant observation at regional meetings of UN agencies and non-governmental organisations and international conferences focused on epidemics in Africa (Addis-Ababa, Dakar), as well as through the analysis of relevant literature and documents.

The emergence of the COVID-19 pandemic led the authors to broaden the scope of PPP data collection from mid-2020 onwards to include topics also related to pandemic response. In 2022, a second set of 10 individual in-depth recorded interviews was held with people involved in preparedness programmes (most of them with whom the authors had already met in 2019). These interviews explored discourses on the strengths and failures of COVID-19 response and their relation with preparedness, identified obstacles to efficient response including those related to vaccination, and collected perceptions on preparedness and uncertainty.

The CORAFSEN project also provided interviews that were analysed for this article, as well as two databases related to COVID-19 in Senegal. Over 60 individual interviews were held in October 2020 with people from the general population to explore their perceptions of vaccine and vaccination before the launch of the national campaign. News articles, online publications, and audio or video broadcasts related to COVID-19 were collected systematically from national and regional media between March 2020 and April 2022, providing a database with more than 4,000 references (with 1 in 8 containing the keyword on 'vaccination' or 'vaccine'). Fake news on social media related to COVID-19 was also systematically collected from March to October 2020, resulting in a database of 125 documents (with 32 items related to vaccines). CORAFSEN defined fake news as text, audio, video, and image messages where the veracity was questionable according to the receivers (Senegalese young research assistants).

In March 2021, observations of 13 vaccination collective sessions were held in Dakar and Ziguinchor as part of CORAFMOB, and 38 individual interviews were conducted with participants, vaccine refusers, and health professionals, who completed CORAFSEN interviews in exploring reasons for vaccine acceptance. This paper is based on content analysis of all data sets and cross-comparison guided by the identification of nexuses, aided by observation facilitated also by the authors' professional positions which ensure immersion in an infectious disease research centre within Dakar University Hospital (Centre régional de recherche et de formation à la prise en charge de Fann).

Results

Preparedness for vaccination in Africa

Generally speaking, vaccination preparedness follows a specific temporality compared to other fields, with time allotted for vaccine research and development, and the establishment of production lines shaping the roll-out of vaccination. Research on vaccine preparedness was seldom a research focus before the COVID-19 pandemic.

The idea that a COVID-19 vaccine could be developed within a year – while providing only temporary protection due to the emergence of variants – was floated globally as early as February 2020 (Parviainen *et al.*, 2021). Early on, the Africa Centres for Disease Control and Prevention (Africa CDC) became involved in population-based vaccine trial development platforms. At the same time, international and regional organisations, foundations, and public-private partnerships converged to organise rapid access to vaccines and equitable and safe immunisation across the globe in the context of competition for provision on the global vaccines market. The UN-driven COVID-19 Vaccines Global Access (COVAX) initiative, part of the Access to COVID-19 Tools Accelerator (ACT-A), was launched in April 2020, before any vaccines had become available and validated (WHO n.d.). Analyses of the results of this initiative in terms of capacity to deliver vaccines show its relevance, initial poor performance, and ultimately its successes in spite of limitations (Hotez *et al.*, 2021; Sachs *et al.*, 2022; Usher, 2022; WHO n.d.).

The main obstacle faced by COVAX in supplying vaccines to Africa in 2020 and 2021 was the lack of available doses due to preemption through direct contracts between vaccine companies and the governments that had paid the highest prices. Another reason was the interruption of exports between March and August 2021 from the Serum Institute of India, the world's leading vaccine producer contracted by COVAX to manufacture and supply vaccines based on Oxford–AstraZeneca technology, when India faced a major epidemic peak. Meanwhile, the urgency of accessing vaccines in Africa increased in late 2020 and again in early 2021 when new waves of COVID-19 infection reached the continent, alongside an intensified focus on variant surveillance and vaccine development, considered as a key to COVID-19 management in the future (Leach *et al.*, 2022b).

By June 2021, Africa still had less than 1% of total doses delivered globally, and African-led initiatives such as the African Union Common Platform for Vaccine Procurement and later the African Vaccine Acquisition Trust (AVAT) added their support. China and Russia, along with other countries, had offered to supply African countries directly with their vaccines since December 2020. Bottlenecks were resolved, and supply management became fully efficient at the regional level by the end of 2021 (Sachs *et al.*, 2022).

In addition, projects to expand vaccine production in Africa and accompanying regulatory frameworks were launched in a few countries including Senegal, as part of a longer-term vision for greater self-sufficiency on the continent (Africa Union, Africa CDC, Africa Union Development Agency [AUDA]-NEPAD Continental Free Trade Area [CFTA], 2021; Irwin, 2021). This chronology of vaccine supply and availability in Africa, as well as the multiple routes of supply for various vaccines, with different technologies, origins, and financial and political implications, had

social consequences at regional and national levels, as shown by the analysis of 'vaccine anxieties' in Sierra Leone and Uganda (Leach *et al.*, 2022b).

The immunisation preparedness process in Africa and Senegal

In August 2020, the WHO Africa office established a COVID-19 Vaccine Readiness and Delivery Task Force, with support from Africa CDC. In preparation for the roll-out, countries were invited to develop immunisation plans covering coordination, financing, legislation, logistics and cold chain, pharmacovigilance, evaluation, and 'demand generation'. African countries were provided with a Vaccine Readiness Assessment Tool (VIRAT), to be used by ministries of health with support from WHO and UNICEF. Aspects to be evaluated included regulations, planning and coordination, costing and funding, target populations, delivery strategies, supply chain, human resources, vaccine acceptance and uptake, safety monitoring, and immunisation monitoring (WHO, 2020b). By the time the vaccines were expected in late 2020, many countries were considered not ready for a mass COVID-19 vaccination campaign or 'ill-prepared', according to experts and based on self-evaluation by VIRAT. In January 2021, this tool showed an average score of 35% for the continent, instead of the expected 80% (Ekwebelem *et al.*, 2021). Among technical issues, experts stressed the need to involve populations, to develop access strategies for high-risk and vulnerable populations, and to address concrete concerns of populations such as procedures and risks attached to vaccination (Ekwebelem *et al.*, 2021).

Senegal completed the preparedness self-assessment process with the VIRAT tool in October 2020, and results showed that the country was 'prepared' for 60% of the sections, 'preparing' for 37%, and 'unprepared' for 3%. The Ministry of Health launched a technical group, engaged with COVAX for free supply of vaccines up to 20% of the target number of doses (and supply at reduced cost beyond 20% depending on availability), with technical assistance and support for cold chain procurement. Strategic choices were defined: priority targets were people over 60 years of age, those with comorbidities (hypertension, diabetes, and other chronic diseases), and frontline health workers; vaccine types/brands were to be selected on the basis of safety, efficacy, conservation standards, number of doses required, and packaging; they would be delivered by the Expanded Program on Immunization (EPI) and community health workers since no regular immunisation was offered at that time to adults by the health system. A roadmap was established, and the main challenges were identified as the availability of vaccines, adherence of the population and health workers to vaccination, mobilisation of domestic resources, and the successful introduction of vaccines and pharmacovigilance.
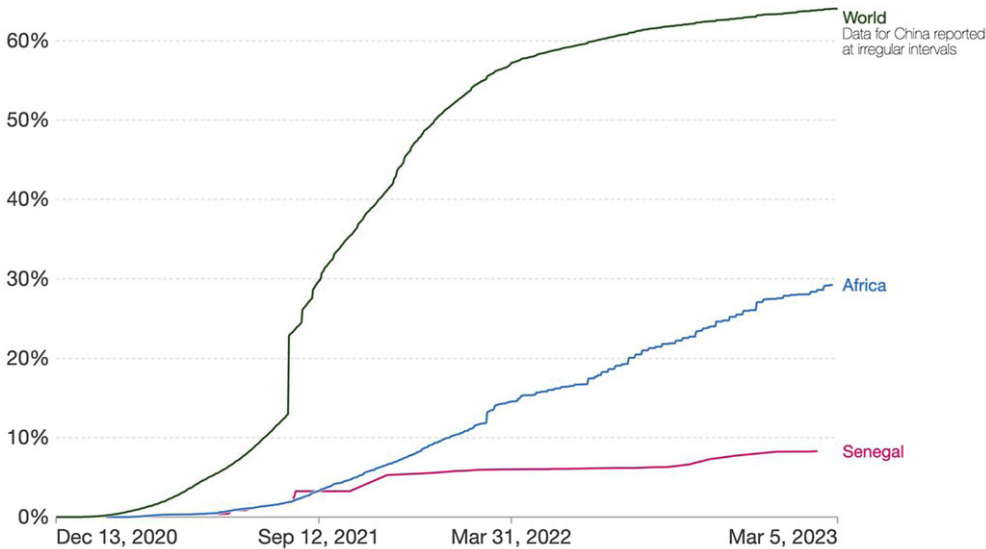
The first 'COVID-19 Vaccination Plan' was released in January 2021(Ministère de la Santé et de l'Action Sociale, République du Sénégal, 2021). Costs per dose were estimated at between USD 4 for the Covishield (Oxford–AstraZeneca) vaccine and USD 72 for the Sinopharm vaccine excluding consumables (syringes, safety boxes) associated with the vaccines. Covishield vaccines were obtained free of charge through the COVAX Facility and within its limits; some vaccines were the subject of bilateral donations, others would be purchased by the country, and some of them with the support of AVAT. Senegal's goal was to vaccinate, in two phases, 20% of the population (in the priority population) by June 2021 and 90% of the population by July 2022. To achieve this, in addition to training health professionals, it planned to raise awareness among 'organised groups, networks, and civil society organisations', but the communication plan was not explained in detail.

Vaccination strategies and uncertainty

The implementation of vaccination in Senegal began on 23 February 2021; 2 years later, 1.4 million people (8% of the population) had completed primary vaccination. This share was

Figure 1. Share of People Who Completed the Initial COVID-19 Vaccination Protocol. Total Number of People Who Received All Doses Prescribed by the Initial Vaccination Protocol, Divided by the Total Population of the Country.
Source: Official data collated by Our World in Data.
Alternative definitions of a full vaccination, for example, having been infected with SARS-CoV-2 and having one dose of a two-dose protocol, are ignored to maximise comparability between countries

much lower than the Africa and the world shares, as shown in Figure 1. As of 31 May 2021, only 2.61% of people in Senegal had received at least one dose, and 0.40% had received a full schedule (Mathieu *et al.,* 2020). As of 31 May 2022, these rates were 8.41% and 6.07%, respectively, far from the target of 90% of people vaccinated in the general population that was set in Senegal's national strategy in early 2021 (Ministère de la Santé et de l'Action Sociale, République du Sénégal 2021).

A series of constraints and uncertainties were encountered by social actors that contributed to the gap between preparation efforts and what actually happened with the vaccination process in Senegal. In the sections that follow, the authors examine four nexuses of incertitude identified through their grounded research: (1) material uncertainty in vaccine supply, (2) ambiguity about the aims of vaccination, (3) uncertainty related to vaccine side effects, and (4) uncertainty of vaccination strategies based on a lack of scientific knowledge. For each nexus, the authors examine how uncertainty was constructed based on knowledge and on social negotiations, for vaccines that circulated as 'commodities' as well as 'ideas'. The findings are presented in the following sections as they occurred chronologically during the implementation of COVID-19 immunisation in Senegal.

Nexus 1. Uncertainty of vaccine supply

At the end of 2020, the Senegalese authorities wanted to have vaccines as quickly as possible, so an agreement was reached with China for the supply of 200,000 doses of the Sinopharm vaccine. These doses made it possible to launch the vaccination campaign on 23 February 2021, supplemented 10 days later by Oxford–AstraZeneca vaccines provided by COVAX, part of the

1.2 million doses expected (International Vaccine Access Center, VIEW-hub 2022). Senegal was thus the first West African country to begin a mass vaccination campaign with a great deal of publicity showing political, medical, and religious authorities, including President Macky Sall, receiving their injections. Frontline health workers were vaccinated at their workplaces. The capital's health centres, where the vaccines were first given, were besieged by people who had seen the media coverage and queued up until the daily allotments of vaccines were exhausted. Facility health staff announced the prioritisation criteria of people over 60 years of age and with chronic diseases to the queues. Three weeks later, the desire to respond to requests and the availability of vaccines led authorities to open up vaccination to adults and adolescents in the general population.

To complete primary vaccination, both Covishield and Sinopharm vaccines require a second dose after 3 months. However, the expected additional doses were not delivered by COVAX, following the ban of Covishield exports from India during the country's own outbreak crisis. In early May 2021, it was reported that Senegal had administered all the doses it had received so far. Senegal felt forced to turn to other suppliers for the Johnson & Johnson, then Pfizer vaccines, when they became available. Vaccine supply remained highly erratic and insufficient until September 2021, with at least two periods from several weeks to 2 months when health facilities had stock-outs and were unable to meet demand, even for people from priority populations. There were also a few periods when only one type of vaccine was available, making it impossible to comply with the primary immunisation protocol based on two injections of the same type of vaccine. From February to September 2021, about half of vaccines were supplied through bilateral channels, either through donations or commercial contracts, and the other half by COVAX, with less than 5% through AVAT. The balance between channels has subsequently changed. By February 2023, all COVID-19 vaccines had been supplied first by COVAX (83.92%), while AVAT and bilateral channels accounted for 8.15% and 7.92%, respectively (Africa CDC, 2023).

The health authorities responsible for planning the vaccine supply and immunisation campaign faced uncertainty, first about the dates, types, and amounts of vaccines available and second about the capacity for production of biomedical equipment and transport facilities, under the severe constraints of cold chain and vaccine storage temperature. The decision to contract a supplier also involved taking into account the scientific information available on each vaccine type, which remained very limited for some. Bilateral contracting was also linked to geopolitical considerations and prior economic relationships, as were vaccine donations with political implications. Global structural inequalities not only delayed but reinforced uncertainties about vaccine supply with consequences for later stages, including vaccine distribution and delivery.

From June to August 2021 during the third epidemic wave due to the Delta variant (Mathieu *et al.,* 2020), numerous cases and deaths, particularly of publicly known people, increased risk awareness in the population. Despite the establishment by the Ministry of Health of an online platform to identify the people in the priority categories willing to be vaccinated and manage demand, requests for vaccination at times exceeded these categories. Targeting vaccination to priority populations was jeopardised by the lack of information in health services, where the authors observed health workers negotiating on-the-spot contradictions between vaccine recommendations and a lack of vaccines. Individuals who the authors interviewed described strategies to obtain a first or second dose: many mobilised their social capital to get into a vaccination site sometimes far from their home but with vaccines available or followed long routes from one vaccination site to another without being able to find a dose. Finally, many people reported getting tired of obstacles and abandoning their search for vaccination. 'I came three times for my second dose and three times there was no vaccine, I wasted my working time, I'm not coming back' (Man, 31–40, vaccinated with one dose), one man explained.

Supply difficulties gradually faded in 2021 and by 2022 had transformed into uncertainty about the country's capacity to use the vaccines in stock and therefore about the quantities to be ordered. In addition, regulatory and reallocation delays led to shortened periods of expiry for vaccines.

This combined with delays in donors' decisions and management created another constraint and became a matter for protest by public health officials at the regional level (Africa Union *et al.,* 2021; Afolabi *et al.,* 2021; Feinmann, 2021; Barnéoud, 2022). Finally, these difficulties reflected the social effects of 'uncertainty' as defined in Stirling's 'incertitude' model (1999), such as the changing concerns for health authorities from supply lack to excess and the entanglement for populations between vaccine access and demand.

Nexus 2. Ambiguity about the aims of immunisation

While official communication on COVID-19 vaccines in Senegal began with the launch of the vaccination campaign in February 2021, these vaccines had already been the subject of intense informal communication on the internet and social networks in West Africa for almost a year. This lay communication focused on the meaning of vaccination in Africa and articulated two notions that circulated in Senegal and in French-speaking West Africa. First, suspicions spread around Africa's use as a research laboratory by Westerners who want to test vaccines on the continent for their own benefit. This notion was already well established before the pandemic as a legacy of the colonial period and fuelled by experience with research for other vaccines like hepatitis B that had been conducted on the continent without benefiting the population (Moulin *et al.,* 2018). A second notion suggested that Africans were minimally vulnerable to COVID-19, either through 'natural resistance' or owing to African pharmacopoeia. Both ideas were widely spread among the people the authors interviewed in Dakar in October 2020, the majority of whom stated that they would refuse vaccination.

On 1 April 2020, two medical doctors raised the possibility of setting up studies on the protective efficacy of the bacille Calmette-Guerin (BCG) vaccine against COVID-19 infection among sex workers in Africa on LCI (La Chaine Info), a French international TV channel. This discussion, which did not consider ethical issues nor previous controversies about medical research among sex workers in Cameroon (Folayan and Peterson, 2020), provoked a great deal of protest in French-speaking Africa and among the African diaspora in Europe. Several petitions based on the idea that white doctors wanted to take advantage of the vulnerability of sex workers and consider Africans as guinea pigs were shared on social networks by celebrities, including footballers and other personalities popular with young people. A few voices pointed out that BCG research had already begun on other continents, that sex workers are vulnerable people who need support and a better knowledge of the COVID-19 protection available to them, and that vaccine research is needed for vaccine ownership by African populations (Eboko, 2020). This controversy reinforced the perception that vaccine trials are implemented in Africa by Westerners for their own good, motivated by structural racism. The 'LCI doctors case' revived memories of colonial management of epidemics, where injections – whether vaccines or treatments – left painful scars (White, 2000; Lachenal, 2017; Tilley, 2020; Leach *et al.,* 2022b). As one man explained, '*Even if COVID did exist, I'd say it's more to do with a world order or a vaccine trial they want to impose on Africa*' (Man, trainer, 41–50 years, not vaccinated).

Meanwhile, from February to March 2020, the Senegalese population was exposed to images of African students living in China who survived the disease in a context where death was shown to be 'around any corner'. Comments in the media claimed that the virus was defeated by Africans thanks to their biological resistance. 'African resistance' combined with 'African treatments' for prevention and care was also mentioned to explain that in Senegal, the population experienced mild pandemic waves with a limited number of cases and less than 500 deaths in 2020. In parallel, the limited effects of the pandemic in Africa, contrary to the predicted catastrophe, became a matter of discussion among scientists and global health experts at the global and regional level where reasons for this so-called 'paradox' were under scrutiny (Ghosh *et al.,* 2020).

In February 2020, Professor Raoult, a French microbiologist, began to promote chloroquine on YouTube as a treatment that would quickly put an end to the pandemic

(Institut Hospitalo-Universitaire Méditerranée Infection, 2020). His discourse gained particular traction in Senegal, not only owing to his legitimacy as a medical authority but also because of his connection with the country due to his childhood residence in Dakar and to the work of the Franco-Senegalese research team on infectious diseases he had led over the past decades. The popularity of chloroquine as an accessible and familiar treatment, used against malaria until the 1990s, shaped the social perception of COVID-19 as a 'malaria-like disease', less exceptional in reality than it was considered by political authorities (Desclaux, 2020; Kadiri and Ollivier, 2020).

Later, the promotion in Senegal (as in other African countries) of Covid-Organics, a remedy championed by the President of Madagascar as a compound containing Artemisia, reinforced the trivialisation of COVID-19 as prevented by a local and renowned popular anti-malarial drug. These perceptions of COVID-19 were explicit in the interviews the authors conducted in Dakar in October 2020 with people from varied social backgrounds. Many respondents mentioned that, given the limited severity of the disease for Africans and the availability of local preventive treatments, a COVID-19 vaccine was unnecessary in Africa. This reinforced the idea that vaccines had been introduced only for testing, to be provided later in developed countries where they were urgently needed. Some people also implied that vaccine provision aimed at discrediting African pharmacopoeia treatments. As one man described, 'No need for [vaccines]. *Islam and traditional remedies are highly effective*' (Man, security guard, over 60, not vaccinated).

Meanwhile, social networks relayed global messages, most of them also salient on other continents (Johnson *et al.*, 2020): they suggested that the pandemic was caused by global actors who have either deliberately spread a virus or disseminated false news about the epidemic and its vaccine as a weapon to achieve undeclared goals. These messages were interpreted and/or adapted in Africa, reinforcing other messages in Senegal that were sometimes relayed by online media or traditional press. They intersected with earlier perceptions of global health as a field of exploitation of Africans by powerful institutions or individuals to extract biological or monetary resources, to dominate populations, or to conduct experiments. Some global messages, such as Bill Gates' 2015 talk about the need for pandemic preparedness (Gates, 2015), were transformed to indicate nefarious intent. In this case, the presumed goal of population control through 5G chips injected with a vaccine resonated with locally constructed online messages about white doctors injecting the virus into children in Casamance (Southern Senegal region). By mid-2020, the public's perception of the threat partly shifted from the COVID-19 pandemic to the COVID-19 vaccine.

Although new and more concrete concerns about the vaccine emerged when the vaccination campaign was launched in February 2021, and demand for the vaccine increased during the third wave of the pandemic, 'ambiguity' as defined by Stirling (1999) remained, underlying social discourses. The theme of political connections and conspiracy developed, targeting the president of Senegal for his relationship with Bill Gates and with governments from the Global North supposed to dictate the vaccine policy, in a context of political contestation at the national level. For some, vaccines remained a 'political weapon' used against the promotion of local African solutions to COVID-19 (such as African preventive remedies, including chloroquine) or for population control by national or global powers. These uncertainties about the purpose of vaccination were fed by the puzzled perceptions of an outbreak that provoked merely 2000 deaths in 2 years but brought disproportionate economic effects, hidden profits derived at various levels, and a justification for a state of emergency that lasted long after the initial epidemic wave.

Nexus 3. Uncertainty on vaccine side effects

For people who had a biomedical understanding of vaccines, including first-line health professionals, vaccine safety was a concern for two reasons: adverse events and the rapid expiration of doses. The increase in demand experienced at the beginning of vaccination lasted until March 2021, when the first reports of adverse events from the Oxford–AstraZeneca vaccine appeared in the global media. This information was broadcast by the international news channels

during this period and widely relayed by the Senegalese media. Cases of atypical venous thrombosis had been reported after vaccination, particularly in France and Great Britain and most frequently in young women. These effects were in addition to temporary pains and swelling at the injection point and the short but severe flu-like symptoms experienced by people of any age. WHO still recommended vaccination, considering that its preventive benefit outweighed the thrombotic risk. Several European countries soon suspended the dispensation of adenovirus-based vaccines while the level of risk was assessed but reopened it again with age limits varying from 30 to 70, according to their group priorities and national vaccine availability. International channels broadcast this information as a series of breaking news, with apparently contradictory decisions linked to procurement in European countries, echoed in the authors' interviews with people in Senegal who expressed their anxieties about adverse events at any age.

This information had a major impact on vaccine perceptions by introducing doubt, in particular among health professionals who were getting their first injections or waiting for their second. They began to wonder if the benefit of the vaccine was greater than the risk of COVID-19, which was then perceived as low in Senegal. This question rekindled other anxieties related to the relatively short development time of the COVID-19 vaccine, which many professionals, as well as the general population, considered insufficient for the vaccine to be safe. Interviews showed that the suspensions of delivery were interpreted as proof of danger. Anxiety was also relayed on social networks about vaccines involving genetic manipulations, based on confusion between vaccine technologies. Among the first-line health workers the authors interviewed in April 2021 in Dakar, some expressed disappointment and distrust of the health authorities and the vaccine manufacturers, who they explained had neglected or hidden data on adverse events. '*At the moment, there's talk of vaccination, but people don't trust it because of rumours about AstraZeneca (vaccine)'s side effects*' (Woman, health worker, 31–40, not vaccinated). Some health workers were accused of knowing about these risks and threatened by people who were anxious about symptoms or death after vaccination.

The absence of scientific information about adverse events associated with the Sinopharm vaccine led some people to consider it safer than others and request the 'Chinese vaccine', especially for their second injection. The donations and COVAX supply of Oxford–AstraZeneca were interpreted by part of the population as coming from the stocks of vaccines that Western countries no longer wanted to use, as shown in online comments of articles. These perceptions were reinforced by an administrative measure applied from June 2021, when France refused entry to its territory for people vaccinated with the Covishield vaccine supplied by COVAX but accepted those vaccinated with Vaxzevria, though these brand names referred to the same technology. Maintained for several months and explained by different approvals from the European Medicines Agency, this measure was also perceived as proof that COVAX vaccines were less effective or more risky than other vaccines, an interpretation developed and disseminated through anti-vaccine posts on YouTube by anti-Western militants such as Nathalie Yamb, called 'La dame de Sotchi' (Yamb n.d.). Social networks also disseminated messages about deaths as adverse effects of the vaccine that were not supported by scientific knowledge.

At the national level in Senegal, the local press first mentioned 'adverse events' in reports of deaths that occurred immediately or within hours after an injection (Fall, 2021). This wording was not challenged by the Ministry of Health, although the causal relationship of vaccines to these events had not been established at the time of publication. The surveillance of adverse events following immunisation (AEFIs) was part of the national immunisation strategy, as requested to qualify for COVAX Facility supply (WHO and UNICEF, 2021). However, the authors' field observations show that vaccinators avoided communicating about adverse effects to people coming for vaccination, either because they lacked information themselves or because they feared provoking refusal or mistrust. Thus, vaccinated people were not aware that they should report post-immunisation symptoms to health workers who would then transmit this information to a committee to investigate the relationship between the event and the vaccine.

The poor performance of the pharmacovigilance system which had registered less than 70 AEFIs by the end of June 2021, a lack of knowledge by health workers, and difficulty in implementing the first reporting level among the public, alongside the uncontrolled allegations by the media about unchecked cases, converged to maintain uncertainty about the adverse effects observed in Senegal. This added to the ignorance or lack of consideration by the media for the pharmacovigilance process and to the lack of communication from health authorities. These shortcomings described in Senegal are also related to the overall limitations of management systems for medical information and have been observed in other African countries (WHO, 2020b; TDR, 2021).

In September 2021, when vaccine uptake was no longer limited by supply, the publication in the media of the number of expired doses that were to be destroyed (20,000 in September and 200,000 in October) (Diop, 2021) fuelled additional concerns about vaccine safety. WHO had previously introduced a regional scheme to redistribute doses between countries and encouraged their use beyond the expiry date (BBC News, 2021), but this measure was not very reassuring for populations that were often already critical towards this international organisation suspected of not defending the interests of Africans. The authors' media surveillance data show that this contributed to safety concerns expressed on social networks, where the destruction of expired doses in Nigeria was shown as a victory obtained by the population against Western institutions (Associated Press, 2021).

The authors' discussions with health professionals in 2021 showed the importance these individuals gave to the 'adverse events' that they experienced themselves or learned about from others. Media publication and the lack of medical communication about risk, which increased collective awareness and experience of mild symptoms, fed into uncertainty and anxiety about more severe unspoken troubles. Concerns about the adverse effects of the Oxford–AstraZeneca vaccine led some health professionals to prefer the Sinopharm vaccine for themselves and loved ones since it had been less targeted by the media. However, the health professionals the authors interviewed did not seem ready to actively recommend any vaccine, particularly Oxford–AstraZeneca, in view of their uncertainties and reservations, which were shared by community actors when COVAX again delivered this vaccine to the country. For all stakeholders, this situation would have been qualified as a combination of 'ignorance' and 'uncertainty' according to Stirling's model (1999).

Nexus 4. Uncertainty about the relevance of vaccination strategy

From September 2021, the Ministry of Health maintained its vaccination strategy, mainly based on the AstraZeneca vaccine now supplied in significant quantities by COVAX. The virus had already circulated widely and conferred immunity on a proportion of the population who had experienced asymptomatic or mildly symptomatic forms of the disease. At the regional level, a meta-analysis of seroprevalence estimation studies in Africa performed in September 2021 suggested 'that up to 65% of the population have some level of conferred immunity' (Balde *et al.*, 2022). After examining various scenarios that included the possibility of re-infection, the authors, mainly experts at WHO, concluded that it was necessary to continue vaccination efforts. Studies at the national and regional levels were in phase with the WHO strategy published in October 2021, which endorsed the targets of full vaccination coverage for 40% of the population by the end of 2021 and 70% by mid-2022 (WHO, 2021; Diarra *et al.*, 2022).

For key actors in Senegal, the strategy raised questions expressed in discussions and meetings among experts and health professionals. Should individuals with antibodies (or neutralising antibodies) be vaccinated? The existing scientific evidence on the benefits of vaccinating people who had already acquired immunity through infection did not seem convincing, the efficacy of immunity that was acquired 'naturally' was still unknown, and there was no simple and inexpensive way to test people to see if they had immunity before vaccination. They also

questioned the appropriateness of providing a vaccine that was not adapted to the circulating variant. There were still major uncertainties about the benefit and cost-effectiveness of a vaccination strategy that targeted 70% of the general population, compared to priority groups. Other unanswered questions about the vaccination strategy included the immunological value of revaccinating every 6 months rather than vaccinating with an appropriate booster when a new wave is announced. This situation would have been qualified as 'ignorance' according to Stirling's (1999) 'incertitude' model.

A national medical expert explained during an interview that strategies must take into account the needs perceived by the population: if vaccination was imposed to achieve 70% coverage, mainly because resources were available at a time when the population did not perceive the need, the population might be reluctant to receive boosters later when a new variant would make a mass campaign essential. Some resident and diaspora experts challenged policy choices and gave their own perceptions through online articles on blogs or national media. Actors explained in discussions that they did not find sufficient elements in recent scientific knowledge to define a strategy that seemed relevant, effective, and safe, as well as adapted to Senegal, without endangering the necessary bond of trust with the population.

Some called for a regional reconsideration of the 70% objective of vaccination coverage in the general population, which seemed too demanding in terms of resources, logistics, and compliance by the population for a temporary and unproven benefit (Msellati *et al.*, 2022). Others argued that the objective of the national strategy was to avoid wasting the doses already received in order to avoid disappointing international donors. These issues raised questions on the capacity to define strategies adapted to the regional level, as stated by one interview respondent:

> For me it is at the African level that we must define our objectives and our priorities. At the global level, the structures . . . have their vision, their policy, their flag and they go in one direction and we only apply. I think it is absolutely necessary that this changes [. . .] (Man, public health officer, 51–60).

In another interview, a Senegalese expert on epidemic response raised these questions and pointed out Africa's 'non-existence in the environment of pharmaceutical research' as a limitation to its autonomy in defining strategies adapted to this region, as he shared in publications (Bousso, 2022; Bousso, 2023). The regional expert review (Balde *et al.*, 2022) argued that while some research informed the response based on serological surveys and operational studies in Africa, more fundamental research is needed to understand the particularities of the African context, particularly related to herd immunocompetence.

These persistent uncertainties about the relevance of the national versus international strategy and about Senegal's capacity to achieve out-of-reach goals could, at least in part, explain the inconsistent commitment of health authorities to promoting immunisation. Communication campaigns were limited, as were strategies to reach people in each vulnerable priority population. The authors' data show that by late 2022, scientific uncertainty about the appropriate strategy for building herd immunity in Senegal combined became entangled with a pragmatic attitude regarding the increasing level of infection-acquired immunity and 'fatigue' about COVID-19 measures due to the long duration of the pandemic.

The need to prioritise recovery and immunisation for other diseases like measles and cholera may have also relegated COVID-19 vaccination to the background of the national immunisation policy. However in 2023, the rate of coverage by boosters was high in a limited proportion of the population who had a primary injection (53%), probably those who were compelled to be vaccinated for work or travel and who had sufficient social capital, information, and connections to the health system. For scientific and medical experts conveyed in regular meetings by the regional coordination platform on COVID-19, these uncertainties stemmed from a lack of research in Africa, which they attributed to

... the lack of human and material resources, autonomy and responsiveness of research in the sub-region, and the fact that COVID-19 was not necessarily a research priority among many other diseases (such as malaria, which remained the leading cause of infectious mortality) (Desclaux *et al.*, 2022).

Discussion: Uncertainty, ignorance, ambiguity, and anticipation

The Senegal Ministry of Health's targets for immunisation defined in January 2021, the completion of primary vaccination for 100% of priority groups or 70% of the population by mid-2021, were not met nor was WHO's later target for 70% of the population by mid-2022. Though WHO later advised to consider actual rates as an 'element of comparison between countries' (WHO, 2022) rather than as an assessment of achievement, these remained targets, which is usual within the managerial approach common to global health programmes (Adams, 2016). The gap between intended and effective rates resulted from multidimensional discrepancies between what was prepared and what occurred, with challenges to be managed. Besides challenges in the governance of the overall response, including the political considerations explained by Ridde and Faye (2021), the authors identified multiple challenges related to immunisation that were driven by uncertainty.

The evolution of the COVID-19 pandemic, with its waves and variants, is not at the forefront of the uncertainties identified in the field and discussed in this article, as immunisation coverage targets were maintained at the global level regardless of this evolution. Uncertainties about vaccination concerned supply, meaning and aims, side effects, and strategy efficiency. They involved four 'stages' in the social life of vaccines and were linked to various materialities, knowledge, and meanings in different social arenas that correspond to the chronology of the social life of pharmaceuticals (Reynolds Whyte *et al.*, 2002; Desclaux and Egrot, 2015). The interconnections observed between the four axes of uncertainty follow Appadurai's model of social negotiations related to the circulation of a commodity. Other barriers to vaccination uptake may exist beyond those identified by the authors' research, for example, the material conditions of vaccination and the relationships between vaccinators and vaccinatees or the intersection between the exceptionality of the pandemic response and the 'ordinary' vaccination system.

Global/regional/local assemblages as sources of uncertainty

Uncertainties themselves possess concrete features produced by 'complex, non-linear unpredictable systems' (Scoones and Stirling, 2020, p.4). The four areas of uncertainty (supply, meaning and aims, side effects, and vaccination strategy) found by this research correspond to different forms of knowledge, engaged and questioned at different times at national, regional, and global levels. Uncertainties about supply related to the inequitable global order of vaccine production reflected the interplay at the national level between economic, political, scientific, and organisational decision-making factors in the context of multiple constraints and competing and vested interests. They also resulted in the inability to plan and deliver vaccines according to a predefined schedule between February and August 2021.

The resulting practical difficulties for vaccine seekers obliged the development of complex and time-consuming strategies at high cost and shaped perceptions of COVID-19 immunisation as a difficult service to obtain. This uncertainty has been described as 'material' in the sense that it is attached to objects, whose production depends on multiple variables and actors (Goumri, 2021). This form of uncertainty has also been experienced to a lesser extent in high-income countries where it was more brief and limited. In West African countries, these 'external forces' were beyond the capacity of preparation at the national level and needed long-term institutional development at the regional level (establishing vaccine production in Africa and technology transfer and setting up regulatory frameworks).

Uncertainties based on coexisting perceptions about the purpose of vaccination as well as about the meaning of COVID-19, 'ambiguity' according to Stirling's framework, were a major element in the constitution of social representations of COVID-19 vaccination in the Senegalese population from April 2020 onwards. The perception of the exploitation of African bodies for experimentation through vaccination was also described in other French-speaking African countries such as Burkina Faso, Benin, Cameroon (Desclaux and Sow, 2021), and Guinea (Heyerdahl et al., 2023), spread through online social networks.

Tilley (2020) describes how the perception of being treated as guinea pigs in medical interventions is rooted in the memory of the colonial past and still active conceptions of racial hierarchy. The lack of trust described by respondents seemed to be fed by limited awareness about African research and the contributions of African scientists to medical knowledge, resulting in particular from media that presents global scientific research as Western. In social media, actors from the West African diaspora in Europe made connections with global discourses on the conspiracies by powerful individuals and states to dominate populations in Africa and beyond. Seeing these representations articulated within an African identity discourse, political authorities in several West African countries were convinced to oppose vaccines and research for several months.

Although vaccines are known to be the subject of multilevel anxieties and conflicting discourses in all contexts (Leach and Fairhead, 2007; Larson, 2020), preparedness for the COVID-19 pandemic did not include any communication about vaccines before the immunisation campaign began in Senegal – 10 months after the first public celebrities had already spoken up against vaccination. In the meantime, in a context of scientific uncertainty about future vaccines and intense global circulation of adverse representations, a whole range of semantics was offered to individuals to create meaning from vaccination uncertainty and ambiguity.

Uncertainty about vaccine safety among health professionals was fuelled by information broadcast by international news channels from March 2021, before the vaccines were available and without adaptation for an African audience. The first adverse events were described in priority groups in Western populations with high frequencies of chronic disease and advanced age and were presented as vaccine-related rather than population-related, on the basis of a generalisation from a Western population treated as a universal reference. For healthcare workers in Senegal, who were among the first to be vaccinated and who got their information mainly from the international media before training was provided by the Ministry of Health, these data resonated with personal experience.

Without pharmacovigilance data published at the national level to oppose alarmist global information, precise information on the risks associated with vaccines was poorly shared in Senegal. This local ignorance remained despite the recent development in Africa of pharmacovigilance mechanisms that made scientific knowledge on side effects available. Public communication had not been prepared, despite the awareness of the iatrogenic risk that has become more important for the public in its relationship to medicines during the last decades (Badji and Desclaux, 2015).

Uncertainties among public health experts concerning vaccine strategy and its relevance in the aftermath of the third wave also concerned the transition of the pandemic to an endemic mode that could justify a change in vaccine strategy. These uncertainties about the appropriate vaccine strategy are fuelled by the lack of scientific data, that is, 'ignorance' according to Stirling's framework, in the context of 'the African paradox' (Ghosh et al., 2020). They highlight issues of sovereignty regarding research in Africa and the unequal availability of resources for research. They also raise concerns about the global underinvestment in basic research among African populations when such research could provide scientific knowledge of global interest.

Pandemic preparation and the COVID-19 action plan in Senegal focused on the implementation of a global immunisation strategy based on principles and hypotheses with limited scientific knowledge. Several limitations and uncertainties related to COVID-19

immunisation found in Senegal were also salient in other West African countries, such as Sierra Leone (Leach *et al.*, 2022b). These seem to relate to the connection between policy and strategy set at the global and regional levels and the capacity for implementation and subsequent agency located at the national level.

Forms of uncertainty and anticipation for preparedness

Beyond the unpredictability of the epidemic and inevitable organisational constraints, various forms of uncertainty related to vaccination were at stake for different social groups. Besides health authorities and vaccinators, material uncertainty concerned planning, access, and the quality of vaccines available. For the population, ambiguities were embedded in perceptions about the relevance and the benefits/dangers attached to the vaccines. For health agents, interpretations of quickly evolving global medical information that emphasised probabilistic AEFI risk interacted with body experiences and fed uncertainty and anxiety in the absence of factual information from the national level. For national public health experts, a vaccination strategy based on insufficient scientific knowledge and underconsidered African specificity (i.e. scientific 'ignorance') was too questionable to be applied broadly and directly. These heterogeneous forms of uncertainty related to material ignorance about supply, doubts, and ambiguity among coexisting contradictory perceptions about the aims of vaccination, the embodiment of the probabilistic notion of risk about vaccine side effects, and the insecurity of decisions made when scientific knowledge about vaccination strategy relied on 'known unknowns'.

Some challenges could have been anticipated at the national level before COVID-19 vaccination began in Senegal, not necessarily from other countries' experiences, but because they were related to long-standing structural rather than COVID-19-specific drivers. The challenges in perceptions and adherence to vaccines are increasingly a matter of concern in public health and the social sciences. Examining these challenges can inform interventions co-developed with communities to fight conspiracy and anti-vax theories, as part of preparation, that is, before the beginning of the pandemic. The socially constructed meaning given to the risk of COVID-19 and its vaccination could have been better addressed with the population through more participative communication and detailed information. In addition, concerns among health professionals about vaccines' side effects could have been better managed through communication on pharmaco-vigilance data registered at the national level.

Critically reconsidering the experience of previous epidemic and pandemic response efforts with those concerned who faced similar challenges, particularly during the peak of HIV/AID (Jaiswal *et al.*, 2020), could be an efficient way to promote local expertise, as shown by some experiences during the Ebola epidemic (Richards, 2016; Hofman and Au, 2017). This approach requires a reconsideration of the 'expert' mode of preparedness assessment (beyond medico-centric approaches based on metrics) and the development of complementary qualitative assessments of context-related issues and structural interventions, to be defined in a multisectoral and multidisciplinary way. Information transparency, a key factor for trust especially during a crisis (Adhikari *et al.*, 2022), should not only concern scientific data and risk expectations but also decision processes for public health and their limitations (Hirsch, 2022). These processes can be anticipated with a better connection between preparation and research to manage ongoing updates of scientific knowledge.

Conclusion

Public health generally considers that vaccine coverage relies on availability provided by the health system and adherence from the population. The findings of the authors' research show that, far from being solely related to individual biosocial factors, weak COVID-19 vaccine coverage in Senegal was produced by many uncertainties that interacted in different social spaces. Tracing the

social life of the COVID-19 vaccine through these nexuses of uncertainty allows the authors to identify the entanglement of forms of 'not knowing' that were produced during the management of this vaccine by different social actors.

Preparation efforts for COVID-19 vaccination were not sufficient to avoid four social nexuses of 'incertitude' (Stirling, 1999): (1) material uncertainty related to vaccine availability, (2) ambiguity about the meaning of vaccination and the disease that it was supposed to prevent, (3) uncertainty and ignorance related to side effects arising among medical staff, and (4) ignorance about the relevant vaccination strategy shared by scientific and health authorities. Drivers of these uncertainties are important to consider in shaping recommendations for the preparation of future epidemics with pervading uncertainty on risk and response.

Regarding dimensions that involve the global level and its relationships with Africa, the COVAX exceptional facility for vaccine access allowed the Ministry of Health to obtain vaccines but within structural challenges that fuelled uncertainty related to material aspects of supply (volumes, dates, type of vaccine, expiry periods) and control by the country. More investments in producing and sharing scientific knowledge about COVID-19, with a focus on the drivers for the 'limited epidemiological impact' of SARS-CoV-2 in Africa, could have helped push back global scientific ignorance and define a vaccine strategy better adapted (and adopted) on the African continent. At all levels, transparency on decision processes as well as on information is needed, with the creation of social spaces for debate and negotiation that include not only regional and national authorities but also health professionals, scientists, and civil society, as recommended by UNESCO International Ethics Committee (2020, p. 1): 'During a crisis situation with many unknowns, an open dialogue between politics, science, ethics and law is especially necessary'.

The authors echo others who have called for a focus on the agency to direct attention towards relations of power in responding to uncertainty (Scoones and Stirling, 2020; Gross and McGoey, 2022). Considering how nexuses of uncertainty are created and shaped during epidemic preparedness and response can help public health to develop strategies that directly address these social spaces of negotiation, they also recommend addressing equity in scientific knowledge. During the COVID-19 pandemic, the entire world faced scientific uncertainty, yet inequity was seen in how it was addressed and how new knowledge was shared, especially concerning vaccine strategies and side effects. A focus on the production of scientific knowledge about the African context and Africa, especially in countries like Senegal, could go quite far in addressing and possibly preventing the multitude of uncertainties that are produced in social spaces concerning a new vaccination for an unfamiliar disease, for the benefit of the global population.

References

Adams V (2016) *Metrics: What Counts in Global Health*. Durham and London: Duke University Press.

Adhikari B, Yeong Cheah P and von Seidlein L (2022) Trust is the common denominator for COVID-19 vaccine acceptance: A literature review. *Vaccine* **X**(12), 100213. https://doi.org/10.1016/j.jvacx.2022.100213

Afolabi MO, Wariri O, Saidu Y, Otu A, Omoleke SA, Ebenso B, Adebiyi A, Ooko M, Ahinkorah BO, Ameyaw EK, Seidu A-A, Agogo E, Nomhwange T, Salami K, Mohammed NI and Yaya S (2021) Tracking the uptake and trajectory of COVID-19 vaccination coverage in 15 West African countries: an interim analysis. *British Medical Journal Global Health* **6**: e007518. https://doi.org/10.1136/bmjgh-2021-007518

Africa CDC (2023) *Africa CDC Covid-19 Vaccine Dashboard*. Available at https://africacdc.org/covid-19-vaccination/ (accessed 28 September 2023).

Africa Union, Africa CDC, **Africa Union Development Agency (AUDA)-NEPAD Continental Free Trade Area (CFTA)** (2021) *Partnership for African Vaccine Manufacturing (PAVM) "From aspiration to action"*, Concept Note. Africa Union. Available at https://africacdc.org/wp-content/uploads/2021/11/ENGLISH_PAVM_Public-Stakeholder-Engagement_Concept-note_Final-version.pdf (accessed 28 September 2023).

Africa Union, Africa CDC, African Vaccine Acquisition Trust and COVAX (2021) *Joint Statement on Dose Donations of COVID-19 Vaccines to African Countries*. Available at https://www.who.int/news/item/29-11-2021-joint-statement-on-dose-donations-of-covid-19-vaccines-to-african-countries (accessed 28 September 2023).

Appadurai A (1988) *The Social Life of Things: Commodities in Cultural Perspective*. Cambridge: Cambridge University Press.

Associated Press (2021) Nigeria Destroys 1 Million Nearly Expired COVID Vaccine Doses. *Voice of America (VOA)*. Available at: https://www.voanews.com/a/nigeria-destroys-1-million-nearly-expired-covid-vaccine-doses/6365879.html (accessed 28 September 2023).

Badji M and Desclaux A (eds.) (2015) *Nouveaux enjeux éthiques autour du médicament en Afrique: analyses en anthropologie, droit et santé publique*. L'Harmattan Sénégal, Dakar.

Balde T, Oyugi B, Karamagi H, Okeibunor JC, Conteh IN, Ejiofor NE, Atuhebwe P, Nanyunja M, Diallo AB, Mihigo R, Yoti Z, Braka F and Gueye AS (2022) Framing the future of the COVID-19 response operations in 2022 in the WHO African region. *Global Health Action* **15**, 2130528. https://doi.org/10.1080/16549716.2022.2130528

Barnéoud L (2022) Covid-19: le grand gaspillage des vaccins périmés. *Le Monde.fr*. Available at https://www.lemonde.fr/sciences/article/2022/03/29/pandemie-de-covid-19-le-grand-gaspillage-des-vaccins_6119589_1650684.html (accessed 28 September 2023).

BBC News (2021) Coronavirus: WHO urges African nations to keep expired vaccines. *BBC News*, 22 April 2021. Available at https://www.bbc.com/news/world-africa-56848551 (accessed 28 September 2023).

Bousso A (2022) Ten actions for Africa to be ready for the next pandemic. *Medicon Medical Science Journal* **3**(3). Available at https://themedicon.com/journals/medicalsciences/MCMS-03-063.

Bousso A (2023) *Sur les vagues de la Covid-19*. L'Harmattan, Dakar.

Bousso A, Ly AB, Sonko I et al. (2022) The initial management of the Covid-19 outbreak in Senegal. *Medicon Medical Science Journal* **3**(2). Available at https://themedicon.com/journals/medicalsciences/MCMS-03-057 (accessed 28 September 2023).

Desclaux A (2020) La mondialisation des infox et ses effets sur la santé en Afrique : l'exemple de la chloroquine. *The Conversation* 19.03.2020, http://theconversation.com/la-mondialisation-des-infox-et-ses-effets-sur-la-sante-en-afrique-lexemple-de-la-chloroquine-134108 (accessed 28 September 2023).

Desclaux A, Diallo M and Msellati P (2022) Covid-19: Comment la recherche a éclairé la réponse à la pandémie en Afrique. *The Conversation* 30.10.2022. Available at http://theconversation.com/covid-19-comment-la-recherche-a-eclaire-la-reponse-a-la-pandemie-en-afrique-193074 (accessed 28 September 2023).

Desclaux A and Egrot M (eds) (2015) *Anthropologie du médicament au Sud. La pharmaceuticalisation à ses marges*. Paris: L'Harmattan.

Desclaux A and Sow K (2021) Covid-19: Après le défi de l'accès au vaccin en Afrique, l'hésitation vaccinale? *The Conversation* 03.09.2021. Available at http://theconversation.com/covid-19-apres-le-defi-de-lacces-au-vaccin-en-afrique-lhesitation-vaccinale-167015 (accessed 28 September 2023).

Dia N, Lakh NA, Diagne MM, Mbaye KD, Taieb F, Fall NM, Barry MA, Ka D, Fall A, Diallo VMPC, Faye Oumar, Jallow MM, Dieng I, Ndiaye M, Diop M, Bousso A, Loucoubar C, Ndiaye MKN, Peyreffitte C, Fortes L, Sall AA, Faye O and Seydi M (2020) COVID-19 Outbreak, Senegal, 2020. *Emerging Infectious Diseases* **26**, 2771–2773, https://doi.org/10.3201/eid2611.202615

Diarra M, Kebir A, Talla C, Barry A, Faye J, Louati D, Opatowski L, Diop M, Consortium R, White LJ, Loucoubar C and Miled SB (2022) Non-pharmaceutical interventions and COVID-19 vaccination strategies in Senegal: a modelling study. *British Medical Journal Global Health* **7**, e007236. https://doi.org/10.1136/bmjgh-2021-007236

Diop Y (2021) Covid-19: 200.000 doses de vaccins perdues en fin octobre (officiel). *Agence de Presse Sénégalaise* 16 November 2021, http://aps.sn/actualites/societe/sante/article/vaccination-covid-19-200-000-doses-perdus-en-fin-octobre-officiel (Accessed 14 September 2022).

Eboko F (2020) «Non, l'Afrique n'est pas, ni de près ni de loin, la cible privilégiée des essais cliniques». *Le Monde.fr* 08 April 2020. Available at https://www.lemonde.fr/afrique/article/2020/04/08/non-l-afrique-n-est-pas-ni-de-pres-ni-de-loin-la-cible-privilegiee-des-essais-cliniques_6035948_3212.html (accessed 28 September 2023).

Ekwebelem OC, Yunusa I, Onyeaka H, Ekwebelem NC and Nnorom-Dike O (2021) COVID-19 vaccine rollout: will it affect the rates of vaccine hesitancy in Africa? *Public Health* **197**: e18–e19. https://doi.org/10.1016/j.puhe.2021.01.010

Fall A (2021) Effets secondaires du vaccin contre le Coronavirus: "53 cas d'hospitalisation, dont 9 graves et 3 décès." *L'Observateur* 17–18 April 2021, 5266, p. 3

Feinmann J (2021) How the world is (not) handling surplus doses and expiring vaccines. *British Medical Journal* **374**: n2062. https://doi.org/10.1136/bmj.n2062

Folayan MO and Peterson K (2020) HIV prevention clinical trials' community engagement guidelines: inequality, and ethical conflicts. *Global Bioethics* **31**, 47–66. https://doi.org/10.1080/11287462.2020.1773061

Foreign Policy (2020) *The Global Response Index* 5 August 2020. Available at https://globalresponseindex.foreignpolicy.com (accessed 28 September 2023).

Gates B (2015) The next outbreak? We are not ready. *TED Talk*, 3 April 2015, Available at https://www.youtube.com/watch?v=6Af6b_wyiwI (accessed 28 September 2023).

Ghosh D, Bernstein JA and Mersha TB (2020) COVID-19 pandemic: The African paradox. *Journal of Global Health* **10**, 020348, https://doi.org/10.7189/jogh.10.020348

Goumri M (2021) L'ignorance matérielle, *Revue d'anthropologie des connaissances* 15 https://doi.org/10.4000/rac.25214

Gross M and McGoey L (2022) *Routledge International Handbook of Ignorance Studies*. London: Routledge.

Heyerdahl LS, Le Marcis F, Nguyen T, Alenichev A, Camara BS and Grietens KP (2023) Parallel vaccine discourses in Guinea: 'grounding' social listening for a non-hegemonic global health. *Critical Public Health*. https://doi.org/10.1080/09581596.2023.2245964

Hirsch E (2022) *Une éthique pour temps de crise*. Paris: CERF.

Hofman M and Au S (2017) *The Politics of Fear: Médecins sans Frontières and the West African Ebola Epidemic*. Oxford: Oxford University Press.

Hotez PJ, Batista C, Amor YB, Ergonul O, Figueroa JP, Gilbert S, Gursel M, Hassanain M, Kang G, Kaslow DC, Kim JH, Lall B, Larson H, Naniche D, Sheahan T, Shoham S, Wilder-Smith A, Sow SO, Strub-Wourgaft N, Yadav P and Bottazzi ME (2021) Global public health security and justice for vaccines and therapeutics in the COVID-19 pandemic. *EClinicalMedicine*. https://doi.org/10.1016/j.eclinm.2021.101053

Institut Hospitalo-Universitaire Méditerranée Infection (2020) *Coronavirus : vers une sortie de crise ?* video 1:44, YouTube, Available at https://www.youtube.com/watch?v=8L6ehRif-v8 (accessed 28 September 2023).

International Vaccine Access Center (IVAC), VIEW-hub (2022) *Current Vaccine Intro Status*. Johns Hopkins Bloomberg School of Public Health. Available at https://view-hub.org/vaccine/covid (accessed 28 September 2023).

Irwin A (2021) How COVID spurred Africa to plot a vaccines revolution. *Nature*. https://doi.org/10.1038/d41586-021-01048-1

Jaiswal J, LoSchiavo C and Perlman DC (2020) Disinformation, misinformation and inequality-driven mistrust in the time of COVID-19: Lessons unlearned from AIDS denialism. *AIDS and Behavior* **24**, 2776–2780. https://doi.org/10.1007/s10461-020-02925-y

Johnson NF, Velásquez N, Restrepo NJ, Leahy R, Gabriel N, El Oud S, Zheng M, Manrique P, Wuchty S and Lupu Y (2020) The online competition between pro- and anti-vaccination views. *Nature* **582**, 230–233. https://doi.org/10.1038/s41586-020-2281-1

Kadiri G and Ollivier T (2020) Coronavirus : l'Afrique, potentiel prochain foyer de l'épidémie, mise sur la chloroquine. *Le Monde.fr* 06 April 2020. Available at https://www.lemonde.fr/afrique/article/2020/04/06/l-afrique-potentiel-prochain-foyer-du-coronavirus-mise-sur-la-chloroquine_6035668_3212.html (accessed 28 September 2023).

Lachenal G (2017) *The Lomidine Files: The Untold Story of a Medical Disaster in Colonial Africa*. Baltimore: Johns Hopkins University Press.

Lakoff A (2017) *Unprepared: Global Health in a Time of Emergency*. Oakland: University of California Press.

Larson HJ (2020) *Stuck: How Vaccine Rumors Start–and Why They Don't Go Away*. USA: Oxford University Press.

Leach M and Fairhead J (2007) *Vaccine Anxieties: Global Science, Child Health and Society*. London: Earthscan Ltd.

Leach M, MacGregor H, Ripoll S, Scoones I and Wilkinson A (2022a) Rethinking disease preparedness: incertitude and the politics of knowledge. *Critical Public Health* **32**(1), 82–96. https://doi.org/10.1080/09581596.2021.1885628

Leach M, MacGregor H, Akello G, Babawo L, Baluku M, Desclaux A, Grant C, Kamara F, Nyakoi M, Parker M, Richards P, Mokuwa E, Okello B, Sams K and Sow K (2022b) Vaccine anxieties, vaccine preparedness: Perspectives from Africa in a Covid-19 era. *Social Science & Medicine* **298**, 114826 https://doi.org/10.1016/j.socscimed.2022.114826

Mathieu E, Ritchie H, Rodés-Guirao L, Appel C, Giattino C, Hasell J, Macdonald B, Dattani S, Beltekian D, Ortiz-Ospina E and Roser M (2020) Senegal: Coronavirus Pandemic Country Profile. *OurWorldInData.org*. Available at https://ourworldindata.org/coronavirus/country/senegal (accessed 26 April 2023).

Ministère de la Santé et de l'Action Sociale, République du Sénégal (2021) *Stratégie nationale de la vaccination contre la Covid-19*. 11 January 2021, 28 p.

Moulin AM (ed) (1996) *L'aventure de la vaccination.* Paris: Fayard.

Moulin AM, Chabrol F and Ouvrier A (2018) Histoire d'un vaccin pas comme les autres : les premiers pas du vaccin contre l'hépatite B au Sénégal. In Delaunay V, Desclaux A and Sokhna C (eds), *Niakhar. Mémoires et perspectives. Recherches pluridisciplinaires sur le changement en Afrique.* L'Harmattan, Dakar and Marseille: IRD Editions, 489–510.

Msellati P, Sow K, Desclaux A, Cottrell G, Diallo M, Hesran J-Y Le, Harczi G, Alfa DA, Touré A and Manigart O (2022) Reconsidering the COVID-19 vaccine strategy in West and Central Africa. *The Lancet* **400**, 1304. https://doi.org/10.1016/S0140-6736(22)01896-7

Our World in Data (2023) *Coronavirus Pandemic (COVID-19).* Ourworldindata.org. Available at https://ourworldindata.org/coronavirus#explore-the-global-situation (accessed 26 April 2023).

Parviainen J, Koski A and Torkkola S (2021) 'Building a ship while sailing it.' Epistemic humility and the temporality of non-knowledge in political decision-making on COVID-19. *Social Epistemology* **35**, 232–244. https://doi.org/10.1080/02691728.2021.1882610

Paul KT and Haddad C (2023) The Pandemic as we Know It. A policy studies perspective on ignorance and nonknowledge in COVID-19 governance. In Gross M and McGoey L (eds) *Routledge International Handbook of Ignorance Studies.* London: Taylor & Francis, pp. 221–233.

Reynolds Whyte S, van der Geest S and Hardon A (2002) *Social Lives of Medicines.* Cambridge, England: Cambridge University Press.

Richards P (2016) *Ebola: How a People's Science Helped End an Epidemic.* London: Zed Books Ltd.

Ridde V and Faye A (2021) *La riposte nationale contre la COVID-19 au Sénégal: de la formulation à sa mise en œuvre.* Working Paper n°50, CEPED, Paris, https://www.ceped.org/fr/publications-ressources/working-papers-du-ceped/wp50 (Accessed 28 September 2023)

Sabahelzain MM, Hartigan-Go K and Larson HJ (2021) The politics of Covid-19 vaccine confidence. *Current Opinion in Immunology* **71**, 92–96. https://doi.org/10.1016/j.coi.2021.06.007

Sachs J, Karim SSA, Aknin L, Allen J, Brosbøl K, Colombo F, Barron GC, Espinosa MF, Gaspar V, Gaviria A, Haines A, Hotez PJ, Koundouri P, Bascuñán Fl, Lee J-K, Pate MA, Ramos G, Reddy KS, Serageldin I, Thwaites J, Vike-Freiberga V, Wang C, Were MK, Xue L, Bahadur C, Bottazzi ME, Bullen C, Laryea-Adjei G, Amor YB, Karadag O, Lafortune G, Torres E, Barredo L, Bartels JGE, Joshi N, Hellard M, Huynh UK, Khandelwal S, Lazarus JV and Michie S (2022) The Lancet commission on lessons for the future from the COVID-19 pandemic. *The Lancet.* https://doi.org/10.1016/S0140-6736(22)01585-9

Scoones I and Stirling AC (2020) *The Politics of Uncertainty. Challenges of Transformation.* London: Routledge.

Stirling A (1999) *On science and precaution in the management of technical risk.* SPRU [based on contributions from O. Renn, A. Rip, A. Salo], Final Report of Forward Studies Unit.

TDR (2021) *Strengthening COVID-19 vaccine safety monitoring in African countries.* 21.06.2021, https://tdr.who.int/newsroom/news/item/21-06-2021-strengthening-covid-19-vaccine-safety-monitoring-in-african-countries (Accessed 28 September 2023).

Tilley H (2020) COVID-19 across Africa: Colonial Hangovers, Racial Hierarchies, and Medical Histories. *Journal of West Africa History* **6**, 155–179. https://doi.org/10.14321/jwestafrihist.6.2.0155

United Nations Development Programme (2022) It's not over till it's over. Bridging the gap in COVID-19 vaccination. *Medium.* Available at https://undp.medium.com/its-not-over-till-it-s-over-6f09c238fc13 (accessed 28 September 2023).

United Nations Educational, Scientific and Cultural Organization, International Ethics Committee (2020) Statement on COVID-19: ethical considerations from a global perspective. UNESCO, IBC-COMEST, 5 p. Available at https://unesdoc.unesco.org/ark:/48223/pf0000373115

Usher AD (2022) ACT-A: "The international architecture did not work for us". *The Lancet* **400**, 1393–1394. https://doi.org/10.1016/S0140-6736(22)02025-6

Utami AM, Rendrayani F, Khoiry QA, Alfiani F, Kusuma AS and Suwantika AA (2022) Cost-effectiveness analysis of COVID-19 vaccination in low- and middle-income countries. *Journal of Multidisciplinary Healthcare* **15**, 2067–2076, https://doi.org/10.2147/JMDH.S372000

White L (2000) *Speaking with Vampires: Rumor and History in Colonial Africa.* Berkeley, Los Angeles, London: University of California Press.

World Health Organisation (2017) *A strategic framework for emergency preparedness.* 29 p. Available at https://www.who.int/publications-detail-redirect/a-strategic-framework-for-emergency-preparedness (accessed 28 September 2023).

World Health Organisation (2020a) *WHO Director-General's opening remarks at the media briefing on COVID-19.* Geneva: WHO. Available at https://www.who.int/director-general/speeches/detail/who-director-general-s-opening-remarks-at-the-media-briefing-on-covid-19—18-august-2020 (accessed 28 September 2023).

World Health Organisation (2020b) *Covid-19 Vaccines: Safety Surveillance Manual.* Geneva: WHO. https://www.who.int/publications-detail-redirect/9789240032781 (accessed 28 September 2023).

World Health Organisation (2021) *Strategy to achieve global Covid-19 vaccination by mid-2022.* Geneva: WHO. Available at https://www.who.int/publications/m/item/strategy-to-achieve-global-covid-19-vaccination-by-mid-2022 (accessed 28 September 2023).

World Health Organisation (2022) *Global COVID-19 Vaccination Strategy in a Changing World: July 2022 update.* Geneva: WHO. Available at https://www.who.int/publications/m/item/global-covid-19-vaccination-strategy-in-a-changing-world–july-2022-update (Accessed 28 September 2023).

World Health Organisation (n.d.) *The Access to COVID-19 Tools (ACT) Accelerator.* Geneva: WHO. Available at https://www.who.int/initiatives/act-accelerator (accessed 28 September 2023).

World Health Organisation, Regional Office for Africa (2021) *Readiness and Response Plan for the WHO African region. 1 December 2021–31 May 2022.* Brazzaville: WHO. Available at https://www.afro.who.int/health-topics/coronavirus-covid-19/strategic-response-who-african-region (accessed 30 April 2023).

World Health Organisation and UNICEF (2021) Module 10: Vaccine safety monitoring, management of adverse events following immunization (AEFI) and injection safety, in: *Guidance on Developing a National Deployment and Vaccination Plan (NDVP) for COVID-19 Vaccines.* MOOC OpenWHO. Available at https://openwho.org/courses/covid-19-ndvp-en/items/4LJt6H43fIMesykH4S1uTt (accessed 28 September 2023).

Yamb N (n.d.) Available at https://www.youtube.com/watch?v=uBj3H3r5eOk (accessed 28 September 2023).