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Longitudinal study on changes in COVID-19 vaccination intentions in Benin and Senegal: Insights from Generalized Estimating Equations (GEE)

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ABSTRACT

The COVID-19 pandemic prompted strict measures and rapid vaccine deployment in Benin and Senegal. This longitudinal study uses Generalized Estimating Equations (GEE) to analyze the evolution of vaccination intent and its determinants, focusing on attitudes, risk perceptions, and social influence. This descriptive and analytical longitudinal study included 546 Beninese and 319 Senegalese individuals aged 18 and above, selected using marginal quotas. Data were collected via Random Digit Dialing (RDD) based on a questionnaire informed by the Theory of Planned Behavior (TPB) and the Health Belief Model (HBM). Influential factors were assessed using GEE models. Vaccination intent increased more significantly in Senegal (+12.5 points, $p = .000$) than in Benin (+5.0 points, $p = .089$). There was a statistically significant increase in vaccine intent among women (+19.9 points) and individuals under 25 (+15.6 points) in Senegal, whereas in Benin, younger respondents showed a decrease (−11.5 points). In both countries, individuals surveyed in the second phase were significantly more likely to express vaccination intent (Benin: OR = 6.9; Senegal: OR = 5.0). Common positive determinants included perceived benefits, social influence, and favorable attitudes toward vaccination. Differences emerged: perceived efficacy and behavioral control were significant in Benin, while safety concerns were a major barrier in Senegal. This study highlights common and context-specific determinants of vaccination intent in Benin and Senegal. It emphasizes the need for tailored communication strategies and efforts to strengthen public trust to enhance vaccine uptake across West Africa.

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Introduction

On March 11, 2020, the World Health Organization (WHO) declared COVID-19 a pandemic. It urged countries to take immediate measures to limit the spread of the infection while adhering to the International Health Regulations (2005).[1] Government responses included strict measures such as bans on public gatherings, social distancing, and lockdowns. Simultaneously, the rapid development of COVID-19 vaccines emerged as a crucial solution to contain the virus and achieve herd immunity.[2,3]

The WHO quickly granted emergency use authorization for several vaccines, including Pfizer (December 31, 2020), AstraZeneca (February 15, 2021), Johnson & Johnson (March 12, 2021), and Sinopharm (May 7, 2021).[4] In this context, the governments of Benin and Senegal launched their vaccination campaigns on February 23 and March 29, 2021, respectively.

In a previous article,[5] we explored the determinants of vaccination intent through a cross-sectional study conducted in Benin and Senegal using structural equation modeling (SEM). This analysis examined the influence of several factors, including individual attitudes toward vaccination, risk and safety perceptions, and the impact of social influence. The findings highlighted contextual variations between the two countries, suggesting that these different dimensions interact differently depending on the socio-cultural environment.[5]

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However, like all cross-sectional studies, this research has inherent limitations due to its susceptibility to measurement and reporting biases. Perceptions can vary depending on the context at the time of data collection, which limits the understanding of dynamics following the launch of vaccination campaigns. This underscores the need for a temporal approach to better capture the determinants of vaccine uptake.

Several longitudinal studies have analyzed the evolution of COVID-19 vaccination intent. A survey by Latkin et al.[6] examined the predictors of COVID-19 vaccine uptake in the United States to assess the impact of vaccine hesitancy, social norms, and political affiliation on actual vaccination. Another study by Chambon et al.[7] analyzed COVID-19 vaccination intent in the Netherlands using longitudinal data collected over six waves between December 2020 and May 2021 to examine the relationships between vaccination intent, attitudes, social norms, and trust over time.

While these two studies provide valuable insights into the evolution of vaccination intent, their analytical approaches have certain limitations. Latkin et al.[6] use logistic regression, which does not account for temporal variations in vaccination attitudes. Chambon et al.[7] apply network analysis but do not directly model individual changes over time. By adopting a Generalized Estimating Equations (GEE) modeling approach, this study offers a more robust framework, accounting for intra-individual correlations and enabling a more precise estimation of changes in vaccination intent based on its determinants. This approach is particularly relevant for analyzing the impact of public health policies on the evolution of vaccination attitudes and the adaptation of behaviors in response to vaccination campaigns.

Thus, this research aims to provide a more detailed and dynamic analysis of vaccination intent in West Africa by examining how perceptions, social influences, and health policies interact over time. By leveraging longitudinal data and a methodology suited to repeated measures, it identifies the most significant factors influencing vaccine uptake. It offers informed recommendations to strengthen communication and intervention strategies for vaccination. This study will contribute to the advancement of knowledge on vaccine hesitancy and its dynamics while guiding future public health policies aimed at improving vaccination coverage.

Materials et methods

Study area

Senegal is a West African country composed of 14 administrative regions. In 2019, the population of Senegal was estimated at 16,209,125 inhabitants, with a relatively balanced distribution (50.2% women and 49.8% men). The ratio of phone numbers per person is 1.1, and the proportion of individuals using a mobile phone at least five times per day increased from 36.4% in 2014 to 73.5% in 2017.[5,8]

With a population of 11,496,140 inhabitants, of whom 50.9% are women, Benin is also a West African country. In 2021, the mobile phone penetration rate was estimated at 101.8%, corresponding to a mobile subscriber base of 12,731,782.[5,9]

Study design

This is a longitudinal, descriptive, and analytical study. Data collection was conducted in two distinct phases in each country. In Senegal, the first phase took place from December 24, 2020, to January 16, 2021, while the second phase occurred from September 10 to November 26, 2021. In Benin, the first phase, conducted from March 29 to May 14, 2021, and the second phase was carried out from December 15, 2021, to January 14, 2022 (Table 1).

Table 1. Data collection periods and start of vaccination campaigns.

	Benin	Senegal
First data collection phase	March 29 – May 14, 2021	December 24, 2020 – January 16, 2021
Second data collection phase	December 15, 2021 – January 14, 2022	September 10 – November 26, 2021
Start of the vaccination campaign	March 29, 2021	February 23, 2021

Study population

The study targeted adult populations in Senegal and Benin, aged 18 and above, who owned a mobile phone requirement due to the telephone-based data collection method.

Sampling

The sampling was designed to ensure the representativeness of adult populations owning a mobile phone. The sample size was determined using simulations based on the following formula:[5,10,11]

$$e = Z_\alpha * \sqrt{1 - \left(\frac{n}{(N-n)}\right)}\sqrt{\frac{p(1-p)}{n}} \tag{1}$$

- N = Parent population size
- n = Sample size
- p = Expected proportion in the population
- α = Confidence level
- Z_α = Value read from the standard normal distribution table

The selected formula aligns with WHO recommendations for population-based health surveys[12] and has been validated in similar vaccination behavior studies in West African contexts.[5]

Simulations indicated that a sample of 1,000 individuals provides an approximate precision of 3% when the parent population exceeds 100,000 (Table 2).

A marginal quota survey was conducted on a target sample of 1,000 individuals.[5,12] This method is particularly relevant in emergency contexts, such as the COVID-19 pandemic, when sample sizes are below 3,000.[5,13,14] A careful selection of quotas can reduce the variance of estimates and narrow confidence intervals. When applied rigorously, quota sampling can provide precision comparable to that of random sampling[5,14] and may even be superior when the sample size is small.[5,14,15]

During the first phase, the survey questionnaire was administered to a final sample of 813 individuals in Senegal and 865 individuals in Benin. The second phase of data collection followed a longitudinal methodology, targeting only individuals who participated in the first phase and provided their consent to respond again. This process resulted in a final sample of 319 individuals in Senegal and 546 individuals in Benin.

Theoretical and conceptual framework

This study's questionnaire design is grounded in two prominent behavioral theories: the Theory of Planned Behavior (TPB) and the Health Belief Model (HBM).[5,16,17] These models were selected for their relevance in understanding the determinants of health-related behaviors.

The TPB provides a framework to assess how individual attitudes, perceived social norms, and perceived behavioral control influence intentions to engage in specific health behaviors. By examining these components, the TPB helps elucidate the motivational factors that lead to the adoption of health-promoting actions.[5,16,17]

Table 2. Simulations on the effects of population and sample sizes on Precision.[5]

N	n	P	α	e
10 000	1000	50%	5%	2.9%
50 000	1000	50%	5%	3.1%
100 000	1000	50%	5%	3.1%
200 000	1000	50%	5%	3.1%
500 000	1000	50%	5%	3.1%
1 000 000	1000	50%	5%	3.1%
10 000 000	1000	50%	5%	3.1%
100 000 000	1000	50%	5%	3.1%

Complementing this, the HBM focuses on individuals' perceptions of health risks and the benefits versus barriers to taking preventive actions. It considers factors such as perceived susceptibility to a health issue, perceived severity, perceived benefits of action, and perceived obstacles, offering insight into the cognitive evaluations that influence health decisions.[5,16,17]

Integrating both the TPB and HBM allows for a comprehensive exploration of the multifaceted processes underlying health behavior decisions. This combined approach captures both the motivational intentions and the cognitive assessments that drive individuals' choices regarding health-related behaviors, enhancing the depth and precision of the study's analysis.[5,16,17]

Description of scales and subscales

Information-seeking behavior on the COVID-19 vaccine

This scale measures proactive information-seeking behavior regarding the COVID-19 vaccine through various means, including regular search behaviors, efforts to understand the vaccine, better, and engagement with information received via social media.[5,16,17] It is divided into three subscales:

- **Regular information search** – Assesses the frequency and consistency of seeking vaccine-related information from various sources (e.g., official websites, media, healthcare professionals).
- **Effort to understand the vaccine** – Evaluates the extent to which individuals actively try to comprehend vaccine mechanisms, effectiveness, and potential side effects.
- **Engagement with social media information** – Measures how individuals interact with vaccine-related content on social media, including sharing, discussing, or verifying the information received.

Cronbach's alpha coefficients ranging from 0.68 to 0.71 (Table 3) indicate an acceptable internal consistency for this dimension across both countries and both phases.[18,19] This suggests that the items reliably measure vaccine information-seeking behavior.

Perception of COVID-19 vaccine safety

This scale aims to assess individuals' perceptions of the safety of the COVID-19 vaccine. It includes three variables measuring different aspects of this perception:[5,16,17]

Table 3. Internal consistency of COVID-19 vaccination-related dimensions (Cronbach's alpha).

		Benin		Senegal	
Scale	Subscale	Phase 1	Phase 2	Phase 1	Phase 2
Information-seeking behavior on the COVID-19 vaccine	Regular information search Effort to understand the vaccine Engagement with social media information	0.681	0.710	0.703	0.705
Perception of COVID-19 vaccine safety	Belief in vaccine safety (reverse-scored) Perceived health risk Concerns about side effects	0.713	0.656	0.698	0.671
Perceptions of the benefits of COVID-19 vaccination	Individual protection against the virus Reduction of virus transmission Protection of loved ones	0.935	0.913	0.935	0.899
Perception of COVID-19 vaccine effectiveness	Perceived preventive effectiveness against infection Risk reduction	0.667	0.617	0.870	0.882
Social influence on the decision to get vaccinated against COVID-19	Social pressure from close contacts Approval from influential people Perspective of healthcare professionals	0.864	0.772	0.871	0.803
Perceived behavioral control	Ease of access to healthcare professionals Trust in healthcare providers Ease of access to vaccination campaigns	0.789	0.603	0.607	0.613
Attitudes toward COVID-19 vaccination	Importance of vaccination Usefulness of vaccination Responsibility toward vaccination Vaccine Safety Desirability of vaccination	0.807	0.759	0.743	0.851

- **Belief in vaccine safety (reverse-scored)** – Measures the extent to which individuals trust vaccine developers to ensure its safety. Responses are often reverse-scored, meaning higher scores indicate greater confidence in vaccine safety.
- **Perceived health risk** – Evaluates whether individuals believe the COVID-19 vaccine poses a threat to their health. Responses indicate the degree to which they perceive the vaccine as potentially dangerous.
- **Concerns about side effects** – Assesses individuals' worries about potential side effects of the COVID-19 vaccine. Responses reflect the level of concern about possible adverse reactions.

With Cronbach's alpha values ranging from 0.65 to 0.71 (Table 3), the internal consistency of this dimension is considered acceptable.[18,19] The associated items consistently assess individuals' perceptions of vaccine safety across both national contexts.

Perceptions of the benefits of COVID-19 vaccination

This scale assesses how individuals perceive the benefits of COVID-19 vaccination, both personally and at the societal level. It includes three statements, each representing a different aspect of these perceptions:[5,16,17]

- **Individual protection against the virus** – Evaluates individuals' perception of the direct personal benefits of vaccination, particularly in terms of protection against infection.
- **Reduction of virus transmission** – Measures individuals' belief in the collective role of vaccination in limiting community transmission and mitigating the impact of the pandemic.
- **Protection of loved ones** – Examines the interpersonal perception of vaccination benefits, highlighting individuals' motivation to protect their close contacts, especially vulnerable individuals.

The highly elevated Cronbach's alpha coefficients, ranging from 0.90 to 0.94 (Table 3), demonstrate excellent internal consistency.[18,19] This indicates that the items consistently measure perceived vaccination benefits, reinforcing the validity of this scale in both countries.

Perception of COVID-19 vaccine effectiveness

This scale assesses how individuals perceive the effectiveness of the COVID-19 vaccine. It includes two statements, each representing a distinct aspect of this perception:[5,16,17]

- **Perceived preventive effectiveness against infection** – Measures individuals' belief in the likelihood of being infected with COVID-19 after vaccination.
- **Risk reduction** – Evaluates individuals' perception of the vaccine's ability to lower the risk of contracting COVID-19. Responses reflect their confidence in the vaccine's effectiveness in reducing infection risk.

Cronbach's alpha values ranging from 0.62 to 0.88 indicate internal consistency ranging from acceptable to very good.[18,19] Although slightly lower in Benin, this dimension overall demonstrates satisfactory validity for measuring perceptions of vaccine effectiveness.

Social influence on the decision to get vaccinated against COVID-19

This scale assesses the perceived influence of social and professional circles on the decision to receive the COVID-19 vaccine. It includes three statements, each representing a distinct aspect of social influence:[5,16,17]

- **Social pressure from close contacts** – Measures individuals' perception that, once the COVID-19 vaccine is available, important people in their lives (family, friends) believe they should get vaccinated. Responses reflect the impact of these close contacts' opinions on their decision.

- **Approval from influential people** – Evaluates individuals' perception that people whose opinions matter to them would support their decision to get vaccinated. It quantifies the influence of this approval on their choice.
- **Perspective of healthcare professionals** – Measures individuals' perception that healthcare professionals would recommend vaccination once the vaccine becomes accessible. It assesses the impact of medical professionals' opinions on their vaccination decision.

With Cronbach's alpha values ranging from 0.77 to 0.87 (Table 3), the internal consistency of this dimension is considered good.[18,19] The items reliably assess the perceived social influence on the decision to get vaccinated in both countries.

Perceived behavioral control

This scale assesses individuals' perceptions of their ease of access to COVID-19 vaccination services and their personal autonomy in making vaccination decisions. It includes four statements, each representing a specific aspect of access and decision-making:[5,16,17]

- **Ease of access to healthcare professionals** – Measures individuals' perception of their ability to reach healthcare professionals or vaccination centers, influencing their sense of control over the vaccination decision.
- **Trust in healthcare providers** – Evaluates the extent to which trust in healthcare providers affects individuals' perceived control over the vaccination process.
- **Ease of access to vaccination campaigns** – Examines individuals' perception of their ability to participate in organized vaccination campaigns, reducing perceived barriers and increasing their sense of control over the process.
- **Personal decision-making** – Assesses individuals' belief that the decision to receive the vaccine is entirely their own, highlighting their perceived autonomy in the vaccination decision-making process.

After analyzing item-test and item-rest correlations (Table A1), it was found that the variable "Personal Decision-Making" exhibited weak correlations with the total scale score, suggesting that it did not measure the same construct as the other items. Additionally, an item-test correlation below 0.20 is often considered a threshold below which an item is deemed non-discriminating and may be considered for removal.[20] Consequently, to improve the reliability and validity of the scale, the removal of the "Personal Decision-Making" item was deemed appropriate.

Attitudes toward COVID-19 vaccination

This scale assesses individuals' attitudes toward COVID-19 vaccination. It consists of four statements, each reflecting a distinct aspect of these attitudes:[5,16,17]

- **Importance of vaccination** – Measures individuals' perception of the significance of getting vaccinated against COVID-19, evaluating the extent to which vaccination is considered a protective measure.
- **Usefulness of vaccination** – Assesses individuals' belief in the effectiveness of vaccination for protecting against COVID-19, reflecting their perception of its benefits.
- **Responsibility toward vaccination** – Examines individuals' perception that getting vaccinated is a responsible act. It measures the sense of duty toward the community.
- **Vaccine Safety** – Evaluates individuals' belief that the COVID-19 vaccine will not pose a health risk, reflecting their perception of vaccine safety.
- **Desirability of vaccination** – Measures individuals' perception of how desirable getting vaccinated against COVID-19 is. It assesses the level of appeal associated with vaccination.

Cronbach's alpha values ranging from 0.74 to 0.85 (Table 3) indicate good to very good internal consistency.[18,19] This confirms that the items reliably measure individuals' attitudes toward vaccination in both contexts.

Data collection and management

The study employed a Random Digit Dialing (RDD) approach[5,21] to facilitate data collection in regions lacking comprehensive telephone directories. To align with the market shares of mobile operators in each country, phone numbers were generated proportionally. These numbers were validated through bulk SMS dispatches, confirming their activity based on delivery statuses. Subsequently, an automated call center contacted the validated numbers, obtained participants' consent, and administered the digital questionnaire using ODK software.

Following a comprehensive three-day training program covering survey methodology and subject matter, data collection was carried out by trained field workers fluent in the primary local languages of both countries.

Quality control measures were embedded throughout the entire data collection process across three phases. Pre-collection quality assurance encompassed instrument validation, pilot testing, careful selection and training of field staff, and securing necessary ethical clearances to guarantee systematic and uniform implementation. During the fieldwork phase, quality control concentrated on addressing unexpected challenges and modifying methodological approaches with proper supervision. Post-collection quality assurance included data harmonization, identification of irregularities, generation of descriptive statistics, before-and-after analyses, and detection of extreme values through visual and statistical techniques.

Participant privacy protection was maintained by eliminating all personally identifiable details, such as geographical coordinates, participant names, and contact information, before any data distribution. The anonymization procedure preserved only subject-area-specific identifier codes within the digital datasets.

Data analysis

Data analysis was conducted using GEE models, a suitable approach for longitudinal data due to its ability to account for within-subject correlations. This method is widely used in public health studies to analyze repeated or correlated data while providing robust estimates.[21] It effectively models vaccination intent by considering the correlation between repeated measurements and delivering reliable estimates of the effects of sociodemographic and perceptual variables.

Dependent variable

Vaccination intent, the dependent variable in this study, was coded dichotomously: 1 indicating a positive intent to get vaccinated and 0 representing a lack of intent. The transformation was carried out by grouping respondents who expressed moderate to strong agreement ("somewhat agree" and "strongly agree") into the "positive intent" category, while those who expressed opposition or indecision ("somewhat disagree," "strongly disagree," and "don't know") were classified under "lack of intent." This dichotomization, a commonly used practice in public health research, facilitates the application of models suited for binary variables.[5,22,23]

Independent variables

The independent variables include sociodemographic factors (data collection phase, gender, age, education level) and vaccination-related perceptions (attitudes, perceived benefits, perceived safety, perceived effectiveness, social influence, behavioral control, and information-seeking behavior). This selection aims to provide a comprehensive understanding of the potential determinants of vaccination intent.

GEE model specification

Given the binary nature of the dependent variable, a binomial distribution with a logit link function was chosen. To determine the most appropriate correlation structure, the Quasi-likelihood Information

Criterion (QIC) was used to assess the goodness of fit of different models.[24,25] A lower QIC value indicates a better balance between model fit and simplicity.

The "Independent" correlation structure appeared to provide the best fit for the data in both countries, with the lowest QIC values (844.93 for Benin and 434.35 for Senegal), indicating that this structure is statistically superior to the other tested correlation structures for modeling vaccination adherence in this context.[24,25] Moreover, the QIC values for different correlation structures were very similar between the two countries, with only minimal differences. This suggests that the choice of correlation structure does not have a significant impact on the overall model fit in these specific cases[24,25] (Table 4).

Model validation

The GEE model was specified with robust standard errors to ensure reliable statistical inferences, even in the presence of heteroscedasticity or incorrect specifications of the correlation structure.[26] This approach guarantees the validity of statistical tests and confidence intervals without requiring specific tests for heteroscedasticity.[27]

A 5-fold cross-validation was also conducted to assess the model's predictive performance on data not used during estimation.[28] This method randomly divides the data into five subsets and, for each subset, fits the model using the remaining four subgroups while predicting the dependent variable in the unused subgroup. Goodness-of-fit measures, such as the Root Mean Squared Error (RMSE) and Brier score, are then calculated for each iteration.

The Brier score is particularly well-suited for evaluating binary prediction models as it measures the mean squared difference between predicted probabilities and actual binary outcomes.[29] The Brier score ranges from 0 to 1, where 0 indicates perfect prediction and values closer to 0 represent better calibration and discrimination. Established benchmarks suggest that Brier scores below 0.15 indicate good predictive performance, while scores below 0.10 demonstrate very good performance for binary health outcomes.[30,31]

For Benin, RMSE values range from 0.311 to 0.344 (corresponding Brier scores: 0.096–0.116), while for Senegal, they vary between 0.266 and 0.395 (Brier scores: 0.073–0.152) (Table 5). The Brier scores demonstrate good to very good predictive performance, with mean values of 0.104 for Benin and 0.093 for Senegal, both well below the 0.15 threshold for good performance[30,31] (Table 5).

Software

All analyses were conducted using Stata 14, employing the XTGEE command[32] to estimate GEE models with the appropriate options for distribution family, link function, correlation structure, and robust standard error calculation.

Table 4. Comparison of correlation structures using the quasi-likelihood information criterion (QIC).

	QIC	
Tested correlation structures	Benin	Senegal
First-Order Autoregressive (AR (1))	845.21	434.39
Exchangeable	845.21	434.39
Independent	844.93	434.35
Unstructured	845.21	434.39

Table 5. Evaluation of predictive performance using cross-validation.

	RMSE		Brier score	
	Benin	Senegal	Benin	Senegal
Estimation 1	0.31	0.28	0.096	0.078
Estimation 2	0.33	0.27	0.109	0.073
Estimation 3	0.31	0.30	0.096	0.090
Estimation 4	0.34	0.27	0.116	0.073
Estimation 5	0.32	0.39	0.102	0.152

Ethical considerations

The study received approval from the National Ethics Committee for Health Research of Senegal (SEN/20/23) and the Local Ethics Committee for Biomedical Research of the University of Parakou in Benin (0308/CLERB-UP/P/SP/R/SA). All participants were informed about ethical considerations and their right to withdraw from the study at any time. They all provided their consent to participate.

Inclusivity in global research

Additional information regarding the ethical, cultural, and scientific considerations specific to inclusivity in global research is included in the Supporting Information.

Results

Sample characteristics

The demographic profiles revealed marked contrasts between the two samples (Table 6). Gender distribution was identical with 61.4% male participants in both countries. Age structure differed considerably: Benin showed most participants under 25 years while Senegal demonstrated a predominance of the 25–59 years group. Educational levels were comparable.

Evolution of vaccination intent between the two data collection phases

Vaccination intent evolution revealed distinct country-specific patterns between phases (Figure 1). Senegal demonstrated a substantial and statistically significant overall increase (+12.5% points, $p < .001$), driven primarily by substantial gains among women and younger adults. In contrast, Benin showed a modest non-significant overall change (+5.0% points, $p = .088$) with heterogeneous age-group responses: significant increases in the 25–59 age group but notable decreases among those under 25 years. These divergent patterns–uniform progression in Senegal versus mixed trends in Benin may be explained by strong governance structure, community engagement, and tailored immunization strategies that effectively addressed social and geographic barriers.[33] In contrast, in Benin, the trends were more heterogeneous, with a notable decline in vaccination intent among younger individuals. Evidence suggests that media and social networks played an important role in spreading fear and misinformation, thereby contributing to hesitancy.[34]

Factors influencing the evolution of vaccination intent in Benin

GEE modeling revealed several significant determinants of vaccination intent evolution in Benin (Table 7, page 24). The temporal effect was substantial, with second-phase participants showing markedly higher vaccination likelihood. Among psychological factors, safety concerns emerged as the primary barrier, while perceptions of vaccine benefits and effectiveness served as positive drivers. Notably, Benin demonstrated a broader range of significant determinants compared to

Table 6. Sample characteristics.

	Benin		Senegal		P-value
	N	%	N	%	
Gender					
Male	335	61.4	196	61.4	0.991
Female	211	38.6	123	38.6	0.991
Age					
<25 years	307	56.2	59	18.5	0.000
25–59 years	205	37.5	223	69.9	0.000
≥60 years	34	6.2	37	11.6	0.062
Education					
Non-educated	199	36.4	133	41.7	0.002
Educated	347	63.5	186	58.3	0.002

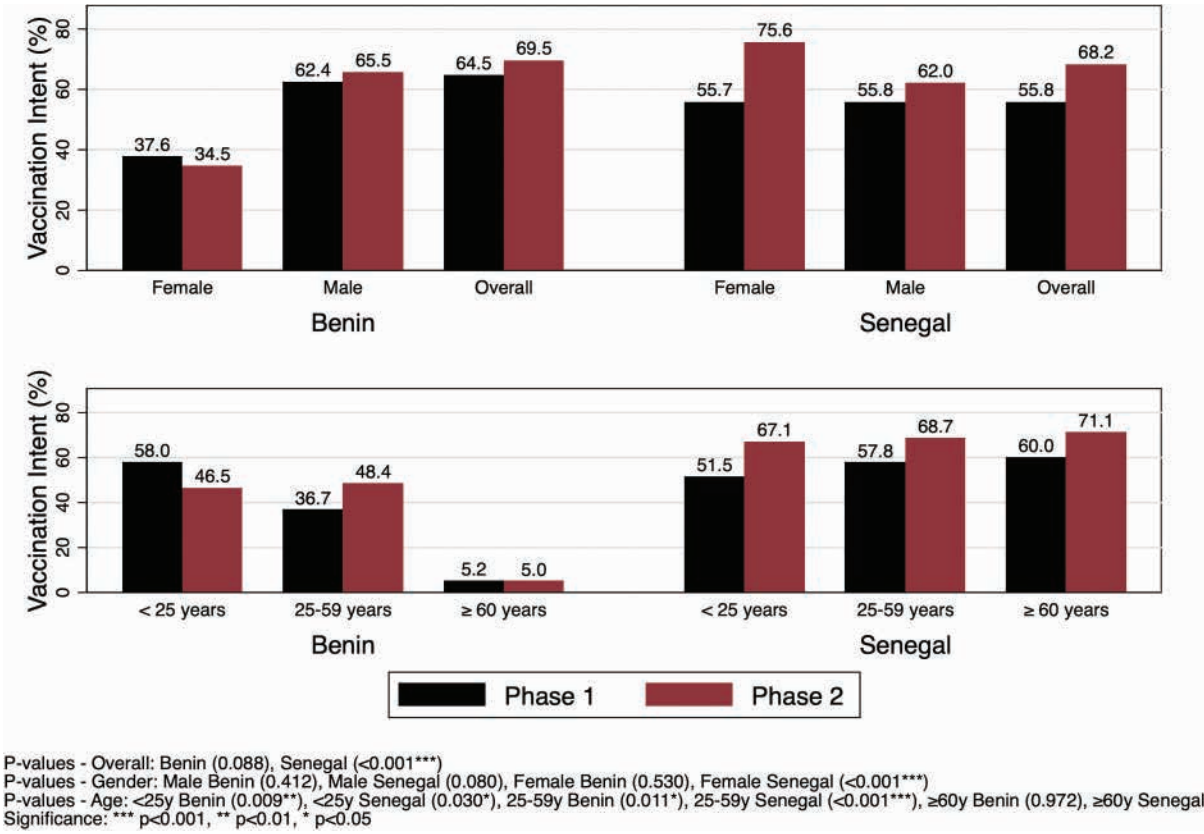

Figure 1. Evolution of vaccination intent by demographic characteristics: Benin-Senegal comparison between two survey phases.

Table 7. Factors associated with vaccination intent in Benin and Senegal.

	Benin		Senegal	
	OR	P>|z|	OR	P>|z|
Data collection phase				
1st phase	Ref.			
2nd phase	6.955	0.000	5.021	0.000
Gender				
Male	*Ref.*			
Female	0.753	0.151	0.946	0.845
Age				
<25 years	*Ref.*			
25–59 years	0.9734	0.896	1.224	0.572
≥60 years	0.926	0.834	1.577	0.383
Education				
Non-educated	*Ref.*			
Educated	0.667	0.074	0.959	0.890
Scale dimension				
Information-seeking behavior on the vaccine	0.943	0.392	1.085	0.103
Perception of COVID-19 vaccine safety	0.781	0.000	0.685	0.000
Perceptions of the benefits of vaccination	1.191	0.005	1.412	0.000
Perception of COVID-19 vaccine effectiveness	1.287	0.005	1.030	0.743
Social influence on the decision to get vaccinated	1.377	0.000	1.310	0.000
Perceived behavioral control	1.203	0.003	0.942	0.345
Attitudes toward COVID-19 vaccination	1.266	0.000	1.254	0.000

Senegal, including both perceived effectiveness and behavioral control as unique predictive factors. Social influence and favorable attitudes completed the determinant profile, emphasizing the multi-faceted nature of vaccination decision-making in this context.

Factors influencing the evolution of vaccination intent in Senegal

Senegal exhibited a more focused determinant pattern with fewer but stronger effect sizes (Table 7, page 24). The temporal progression showed similar magnitude to Benin, but benefit perception displayed the highest impact among psychological factors. Safety concerns remained a persistent barrier with slightly stronger adverse effects than in Benin. Unlike Benin, perceived effectiveness and behavioral control showed no significant influence, suggesting that vaccination decisions in Senegal operate through different psychological pathways centered on attitudes, benefits, and social influence rather than access or effectiveness perceptions.

Differences and similarities between the two countries

Both countries demonstrated standard core mechanisms: significant temporal effects, safety barriers, benefit recognition, social influence, and attitude formation (Table 7). However, country-specific patterns emerged with Benin showing broader psychological engagement (effectiveness, behavioral control) while Senegal exhibited more concentrated effects with higher benefit perception impact. The differential safety concern intensity suggests context-specific risk communication needs, while the unique significance of behavioral control in Benin indicates distinct accessibility challenges not present in the Senegalese context.

Discussion

The results reveal that several perceptions significantly influence vaccination intent in both countries, albeit with some notable differences.

In both contexts, perceived vaccine benefits emerged as the strongest of vaccination intent evolution, confirming but nuancing previous research. Our finding aligns with the work of Brewer et al.[35] regarding the importance of benefit communication. Still our longitudinal GEE approach reveals temporal dynamics that cross-sectional studies cannot capture. Unlike the static relationships documented in traditional HBM frameworks by Rosenstock et al.[36] we demonstrate that benefit perception strengthens progressively during vaccination campaigns, with effect sizes increasing significantly from Phase 1 to Phase 2 (Benin: OR = 1.191; Senegal: OR = 1.412).

More importantly, our comparative analysis reveals contextual variation in the intensity of perceived benefits effects that extends the conclusions of Xiao et al.[37] While their meta-analysis identified perceived benefits as universally necessary for vaccine acceptance, our results show that this effect is more pronounced in Senegal (OR = 1.412) than in Benin (OR = 1.191).

This difference in intensity suggests that the global dimension of perceived benefits resonates differently across West African cultural contexts, challenging the assumption of universal effects derived from studies conducted primarily in Western settings.

These observations indicate that effective awareness campaigns should not only focus on communicating tangible vaccination benefits, but also adapt the intensity and approach of this communication according to local contextual specificities to strengthen trust and promote adherence.

Perceived vaccine safety constituted a significant barrier in both countries, with a slightly more pronounced negative effect in Senegal (OR = 0.685) than in Benin (OR = 0.781), revealing contextual variations absent from previous global analyses. While our findings align with Loomba et al.'s[38] documentation of how safety concerns hinder vaccination intent, our comparative longitudinal design exposes differential cultural responses. Unlike the uniform safety concern patterns reported in Western contexts, our results demonstrate that identical safety information generates varying levels of hesitancy across neighboring West African countries.

This cross-national variation extends beyond our previous cross-sectional findings,[5] which identified safety perceptions as significant but could not capture their differential cultural manifestation. The more substantial safety barrier effect in Senegal may reflect the country-specific factors identified by Fall et al.[39] including inadequate pharmacovigilance data dissemination and systematic distrust toward official information sources–contextual elements that interact with safety perceptions in ways not captured by global studies like the World Bank's[40] regional analysis of COVID-19 vaccine concerns.

Our longitudinal approach reveals that safety concerns persist as barriers even as vaccination campaigns progress, contrast to the assumption that safety perceptions would improve with accumulated real-world evidence. This temporal persistence of safety concerns, combined with their differential intensity across contexts, suggests that safety perceptions are not merely information-deficient but are deeply embedded in local trust systems and historical experiences with health authorities.

These findings indicate that addressing vaccine safety concerns requires culturally tailored approaches that acknowledge varying baseline trust levels rather than universal information campaigns derived from contexts with different institutional credibility.

Social influence emerged as a key factor in both countries. However, its effect was slightly more pronounced in Benin (OR = 1.377) than in Senegal (OR = 1.310), revealing subtle differences in social dynamics affecting vaccination decisions. Our findings confirm Omer et al.'s[41] observations regarding the importance of approval from close contacts, healthcare professionals, and community leaders. Still, our comparative longitudinal approach reveals that the intensity of this influence varies across West African cultural contexts – a nuance absents from previous global studies.

This cross-national differentiation in social influence effects is explained by context-specific factors documented in each country. The more substantial effect in Benin corresponds to Maccaro et al.'s[42] observations that vaccine acceptance there is particularly influenced by social engagement, notably through support from healthcare professionals and traditional healers—a configuration of influential actors that may explain the higher OR observed. This convergence between our longitudinal quantitative data and qualitative anthropological studies reinforces the validity of our tri-dimensional social influence measures (pressure from close contacts, approval from influential people, and healthcare professionals perspectives).

Unlike our previous cross-sectional findings[5] that identified social influence as generally necessary, our temporal analysis reveals that this influence strengthens progressively during vaccination campaigns, suggesting a social amplification effect over time.

These results suggest that engaging community networks, including local leaders and healthcare professionals, constitutes an effective strategy to increase vaccination intent, but that the approach must be adapted to each context's specific influence ecosystem. By mobilizing these influential actors in culturally appropriate ways, it is possible to strengthen vaccine confidence and contribute to higher vaccination coverage in the region.

Overall favorable attitudes toward vaccination significantly influenced vaccination intent evolution in both countries, with similar effect sizes in Benin (OR = 1.266) and Senegal (OR = 1.254), suggesting cross-contextual robustness of this relationship. However, our longitudinal analysis reveals temporal stability in attitude effects that contrasts with the declining trends documented by Greyling and Rossouw[43] in their social media sentiment analysis across ten countries. This divergence suggests that West African contexts may exhibit different attitudinal dynamics from those observed in high-income countries, where positive attitudes tend to erode over time.

Our multidimensional attitude measurement (importance, usefulness, responsibility, safety, and desirability of vaccination) extends the conclusions of Ngangue et al.'s[44] systematic review of COVID-19 vaccine attitudes in Africa, which identified governmental trust and personal experiences as primary determinants. Our results demonstrate that these factors manifest through structured, measurable attitudes that maintain their positive influence even during advanced phases of vaccination campaigns. This temporal persistence of attitudinal effects differs from Tahir et al.'s[45] observations of vaccine belief variability, suggesting that Beninese and Senegalese contexts exhibit attitudinal stability.

These findings indicate that strengthening vaccination intent requires promoting positive attitude development, but that approaches developed in other regional contexts may not be directly transferable. The attitude effect stability observed in our study suggests that interventions aimed at maintaining rather than restoring favorable attitudes may be more appropriate in these contexts, requiring proactive and transparent communication adapted to West African cultural specificities.

Furthermore, perceived behavioral control (OR = 1.203, $p = .003$), an indicator of the perceived ability to access vaccination services, was significant only in Benin, revealing contextual specificity absent from universal theoretical models of vaccination behavior. This divergence between neighboring countries extends Galanis et al.'s[46] observations on how logistical barriers and limited-service access influence vaccination behaviors, by demonstrating that these factors operate differently even within similar geographical and cultural contexts. Unlike studies that treat behavioral control as universally necessary, our results reveal that in Senegal, perceived access to vaccination services does not constitute a significant determinant of intent, suggesting different infrastructure realities or accessibility perceptions.

This Beninese specificity in perceived behavioral control effects nuances the general recommendations of Lin et al.[47] regarding the importance of improving accessibility to overcome perceived barriers. Our results indicate that interventions aimed at enhancing accessibility may be crucial in specific context (Benin) but potentially less prioritized in others (Senegal), even within the same region.

These findings indicate that improving vaccination adherence in Benin specifically requires strengthening perceived accessibility by reducing logistical barriers and improving vaccine distribution. However, this strategy might be less effective in Senegal, where other factors (perceived benefits, social influence) appear more determinant, highlighting the need for differentiated approaches even within apparently similar regional contexts.

Limits

The samples were nationally representative only and did not allow for disaggregation by place of residence or region.

Moreover, only individuals with a mobile phone were surveyed, thereby excluding the most marginalized populations. Indeed, although the use of the marginal quota method helped strengthen the representativeness of the samples compared to the general population, the main limitation lies in the exclusive reliance on telephone surveys, as individuals without mobile phones are often from the poorest households or living in remote areas. This constraint may limit the generalizability of the results, particularly regarding inequalities in access to information and vaccination services.

Additionally, it is generally preferable to include at least three items per scale, as was the case for all measured dimensions except for the perception of COVID-19 vaccine effectiveness. Due to this structural limitation, results from the perceived efficacy dimension were excluded from our primary analyses and discussion. However, they are retained in the results tables for informational purposes only. All interpretations and conclusions are based exclusively on dimensions meeting robust psychometric standards.

Conclusion

The findings of this study highlight both common and specific determinants of vaccination intent in Benin and Senegal. In both countries, perceived vaccine benefits, social influence, and positive attitudes emerge as key drivers of vaccine uptake. However, contextual differences are noteworthy: in Benin, perceived vaccine effectiveness and behavioral control play a significant role, whereas in Senegal, these factors are not determinants. Additionally, while perceived vaccine safety acts as a barrier in both contexts, its impact is more pronounced in Senegal. These results underscore the need to tailor communication and intervention strategies to the specific realities of each country to maximize vaccine acceptance.

These conclusions align with the work of Dubé et al.[48] who emphasized the importance of public trust in vaccines and health authorities to ensure the success of vaccination programs. They recommend communication strategies adapted to sociocultural contexts to address population concerns and strengthen vaccine uptake. Furthermore, Dubé and MacDonald[49] highlighted that understanding and addressing the problems of hesitant individuals is essential to increasing vaccine acceptance and adoption.

Thus, to improve vaccine uptake, it is crucial to implement clear and context-specific communication strategies, enhance transparency and trust in health systems, and actively engage community leaders and healthcare professionals. These approaches will enable an effective response to public concerns and maximize adherence to vaccination programs.

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Appendix

Table A1. Evaluation of the impact of items on the internal consistency of the dimension.

	Item-test correlation				Item-rest correlation			
	Benin		Senegal		Benin		Senegal	
	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2
Ease of access to healthcare professionals	0.82	0.66	0.60	0.72	0.65	0.24	0.30	0.40
Trust in healthcare providers	0.81	0.68	0.72	0.62	0.58	0.34	0.40	0.33
Ease of access to vaccination campaigns	0.80	0.61	0.80	0.80	0.61	0.31	0.56	0.54
Personal decision-making	0.50	0.48	0.53	0.55	0.25	0.11	0.24	0.28