Drivers of vaccine decision-making in South Africa : a discrete choice experiment

Drivers of Vaccine Decision-Making in South Africa: a Discrete Choice Experiment

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Abstract

To increase vaccination coverage, it is essential to understand the vaccine decision-making process. High population coverage is required to obtain herd immunity and to protect vulnerable groups in terms of age (e.g. the very young) or health (e.g. immunodeficiency). Vaccine confidence and coverage in South Africa are relatively low, opening the window for sustained outbreaks of vaccine-preventable diseases in a country facing one of the most severe HIV epidemics in the world. To capture the vaccine-related decision-making process in South Africa, we performed a discrete choice experiment with 1200 participants in December 2017. We asked for their preferences with respect to (1) vaccine effectiveness, (2) vaccine-preventable burden of disease, (3) accessibility of the vaccine in terms of co-payment and prescription requirements, (4) frequency of mild vaccine-related side-effects, (5) population vaccination coverage and (6) local vaccination coverage. We distinguished between decision-making for vaccines administered to the participant, and for vaccines administered to their youngest child. We analyzed the data for each of these groups using a panel mixed logit model and found similar results for decisions to vaccinate oneself or one's child. Vaccine effectiveness was the most important attribute followed by population coverage and burden of disease. Local coverage and accessibility were also important influencers in vaccination behavior, but to a lesser extent. Regarding population and local coverage, we observed a positive effect on vaccine utility indicating the potential of peer influence. As such, social normative influence could be exploited to increase vaccination confidence and coverage. With respect to vaccine-preventable burden of the disease, the marginal utilities showed disease severity to be more important than frequency of disease. Policymakers and health care workers should stress the effectiveness of vaccines together with the severity of vaccine-preventable diseases.

Keywords

Vaccination – discrete choice experiment – behavior – free-riding – decision-making criteria – South Africa

Highlights

- We measured vaccine preferences in South Africa with a discrete choice experiment;

- Vaccine effectiveness and population coverage are key in vaccine decision-making;
- Vaccine utility is also driven by burden of disease and vaccine accessibility;
- Social norms and peer influence dominate rather than free-riding behavior

Introduction

Decades of progress made in control and prevention of infectious diseases are currently under threat by a worldwide increase in vaccine hesitancy and refusal [1]. The number of people perceiving vaccines as unsafe or unnecessary is growing, fueled by a false sense of security due to a decline in vaccine-preventable diseases, amplification of anti-vaccine messages through social media [2] and continued anti-vaccine exploitation of a fraudulent paper linking the measles-mumps-rubella vaccine to autism [3]. Decreasing vaccination coverage is even more concerning as it causes a decline in indirect protection, or herd immunity, which plays a central role in protecting vulnerable individuals (e.g., the very young or immunocompromised) [4]. Understanding what drives individuals' vaccination-related decisions is highly relevant to inform policymakers and vaccine administrators in their efforts to increase or maintain vaccination coverage.

The voluntary nature of most vaccines substantiates the need to take the decision-making process into account. Information deficiencies make it difficult for the public to grasp the potential burden of vaccine-preventable diseases and hence to understand the need for protection. As such, vaccination is to a certain extent victim of its own success; many regions experienced sufficiently high vaccine coverage for several years, leading to very low prevalence or even elimination. I.e. many regions are no longer confronted with the image of the corresponding vaccine-preventable diseases. This could lead to a false sense of safety and the idea that vaccination is otiose. In addition, many studies assume that vaccine decisions are influenced by free-riding behavior, through which individuals would be less inclined to opt for vaccination when they perceive vaccination coverage to be high [5]. As such, they have the opportunity to obtain "free", indirect protection through herd immunity.

Global vaccine confidence was recently examined in 67 countries by Larson et al. [1]. Overall, vaccine sentiments appeared to be inversely correlated with socioeconomic status. The European region was found to have the lowest vaccine confidence regarding vaccine safety. For the African region, pediatric

vaccines were found less important in South Africa than in Ethiopia, Algeria, Ghana, Nigeria and DR Congo. Other studies on vaccine refusal in South Africa refer to the use of the monovalent MeasBio® vaccine that contains porcine gelatin, which is poorly accepted in some religious communities [6, 7]. The country-level coverage of the measles-containing vaccine in South Africa is estimated to be around 60% for the first and second dose [8], which is below the herd immunity threshold of 95% to stop endemic measles transmission [9]. Achieving and maintaining high vaccination coverage is especially important to sustain herd immunity and avoid outbreaks of diseases like measles and protect vulnerable subpopulations like human immunodeficiency virus (HIV) positives. In January-September 2017, 129 laboratory-confirmed measles cases were detected in South Africa in three major outbreaks [7].

At the same time, South Africa faces one of the most severe HIV epidemics in the world, with an estimated 6.4 million people living with HIV in 2012 [10]. Infants born to HIV-infected mothers have lower maternal passive immunity and are likely to acquire HIV. HIV-infected children are more at risk of severe and lethal vaccine-preventable diseases, including measles [11, 12], partly because they are also less responsive to vaccination [13]. Hence, herd immunity is pivotal in protecting this large vulnerable group in South Africa, and this depends largely on whether other South Africans decide to receive vaccination or not. Despite indications of vaccine distrust and skepticism reported by Larson et al. [1], there is to our knowledge no published study on the drivers of individual vaccination decisions in South Africa.

Discrete choice experiments (DCEs) have been used to investigate societal preferences regarding vaccinations in multiple countries and revealed the importance of vaccine-related side-effects [14–19], vaccine efficacy [14–16, 18–20] and vaccine cost [15, 17–19, 21]. A DCE is a surveying technique where respondents are asked to make choices between specified profiles in consecutive choice sets to extract attribute importance and utility values for each attribute level [22]. These utilities represent preferences for an attribute level relative to all other attribute levels.

In this paper we describe the results of a DCE that explored the vaccine decision-making process for a general, unnamed vaccine among 1200 respondents in South Africa. We identified the most influential vaccine attributes and analyzed preference heterogeneity. We distinguished between decisions about a vaccine that would be administered to the participant versus decisions about vaccination of their

youngest child. We discuss our findings in the context of policy-making and modeling vaccination behavior.

Methods

We surveyed individuals in South Africa in December 2017 from an online panel using pre-defined quota on gender, age and ethnicity based on national statistics [23]. Details on the quota and background characteristics are presented in Table 1. The survey was launched on an established panel platform, where only the average time required and credit rewards for filling out the survey were displayed. Panel members opted-in for this survey based on this information only. Only one respondent (>18 years) per household could take part. Respondents filled out the survey for themselves or for their youngest child (<18 years), and accordingly, we classified respondents in an 'adult' or 'child' group. Individuals were first randomly assigned to a group. If a respondent in de 'child' group indicated not to have a child under the age of 18, (s)he was moved to the adult group. In total 2958 panel members started the survey of which: 1431 completed the survey successfully, 725 chose not to complete it, 122 were screened out because they were identified as 'speeders' (completed the survey much faster than the reference time) or 'straight-liners' (responded the same for each question), and 680 were halted after the first part of the survey with background questions when pre-defined sample quota were reached to optimize participant allocation. From the 1431 completed surveys, we selected 600 participants from the adult and child group, separately, to approximate the pre-defined quota for age, gender and ethnicity. Given the state-of-the-art Bayesian optimal design [22] of this study (see appendix A and B), a sample size of 600 is sufficient to estimate all attribute and covariate effects. Participation was incentivized through credit rewards which are, after a delay of 72 hours, transferable into coupons, gift cards, airline miles, etc. The study protocol was approved by the ethics committee of the Antwerp University Hospital, Belgium, (Reference number: 15/2/12) and no physical samples were collected. Data collection was performed according the ICC/ESOMAR International Code on Market, Opinion and Social Research and Data Analytics. Given the observational and anonymous nature of our study, and by resorting to this regulated survey panel, no additional approval from a South African regulator was required.

The survey consisted of four parts probing for participants' background characteristics, vaccine-related attitudes, discrete choice preferences and risk perception on infectious diseases and vaccination.

Background characteristics included gender, age, postal code, educational attainment, job status, family situation, family size, age of youngest child, mother's country of birth, ethnicity, professional experience in the health care sector, experience with severe illness, experience with seasonal influenza vaccination, smoking status and religion. The second part of the survey contained 12 statements regarding vaccination that participants were asked to rate on a 5-point Likert-scale ranging from 'strongly agree' to 'strongly disagree'.

In the third part, the DCE was surveyed using 10 choice sets with 6 attributes to balance between completeness and cognitive feasibility for the respondent. We derived the attributes and their levels (Table 2) from the literature on DCEs in the context of vaccination [14–21] and health economics in general [24–26]. Burden of disease was introduced in a DCE on vaccination risk perceptions in the UK [17] and in a DCE on health prioritization in general [26]. Vaccine effectiveness was included in four studies we retrieved from the literature [14,18,20,26]. We found an attribute describing VRSE in two studies [17,18] and accessibility was included in a variety of descriptions (willingness-to-pay, number of visits, out-of-pocket costs etc.) in five studies [15,17,18,20,21]. We only retrieved two studies that included an attribute on vaccine coverage [15,21], but found the need to include both local coverage as well as population coverage based on the literature covering behavioral change models in infectious disease epidemiology [5].We adopted the survey design from [19], which was created for a multi-country DCE study, except for the description of the attribute on vaccine-related side-effects (VRSE). In the current DCE, we only varied VRSE frequency by explicitly specified VRSE as being mild in both of its attribute levels.

The feasibility of the survey was confirmed through a 'soft launch' in a small sample of the panel. The DCE was introduced to the respondents by a general description and a illustrative choice set with two attributes. Subsequently, we asked the respondents for their preference between two vaccine profiles in 10 choice sets (Figure 1 shows one choice set). We avoided using a technical/epidemiological lexicon to describe attribute levels, resulting in a good understanding by 80 respondents in the soft-launch. We varied three out of six attributes in each choice set and marked the varying attributes in yellow to limit the cognitive burden on the respondents. However, we stressed the importance of taking all attributes into account, corresponding to the methodology described in the literature [26–30]. We designed the DCE to estimate the main attribute effects and all two-way interactions between any of the six attributes, and

'vaccine effectiveness', 'VRSE' and 'accessibility' with maximum precision. To capture all model terms (10 main effects and 24 interaction effects), we constructed a Bayesian D-optimal design [22] of 50 choice sets, divided into five subsets of 10 choice sets (see Appendix A for the choice design and Appendix B for the specification of the prior parameter distribution). These subsets were evenly presented to the participants in both the adult and child group.

The last part of the questionnaire asked participants about their perception of relative severity and susceptibility of measles compared to influenza, leukemia and bladder infection, based on the work of Bults et al. [31].Finally, we asked about their relevant sources of information and their knowledge about measles and measles containing vaccines.

We used the JMP Pro 13 Choice platform [32] to obtain the relative importance ranking of the attributes and the utility values of their levels by estimating a Panel Mixed Logit (PML) model using Hierarchical Bayes. We assumed normally distributed preference parameters without correlation between attributes to accommodate unobserved heterogeneity in the respondents' preferences. Results were obtained after 10,000 iterations, with the last 5,000 used for estimation. The average utility function is the sum of the average values of the attributes' main and interaction effects. We computed the overall significance of the attributes using likelihood ratio (LR) tests and measured the relative importance of the attributes by the logworth statistic, i.e. $-\log_{10}$(p-value of the LR-test). We started the data analysis with a PML model for each group (adult and child), i.e. the model with the main attribute effects and all two-way interactions between an attribute and 'vaccine effectiveness', 'VRSE' and 'accessibility'.

To explore structural differences in the observed preference heterogeneity among subsets of respondents, we estimated two-way interactions between vaccine attributes and background characteristics, vaccine attitudes and risk perception. We first tested the interaction effects with each covariate in separate models. We then constructed a joint model by including all individually significant covariates (p-value <0.05). In this model, some of the covariates turned out to be insignificant, which we then dropped through an iterative process until only significant ones remained.

We obtained additional relative importance rankings of the attributes by sampling 100 sub-datasets without replacement of 700 respondents for which the ethnicity distribution matched that of the

population (i.e. increasing the proportion of Black African respondents to 80.7% and decreasing the proportion of White South Africans to 8.1%). We generated models for each of these sub-datasets, computed and recorded the logworth statistics and calculated the mean and 95% confidence interval for the importance of each attribute using the percentile method.

Results

For the full sample (N=1200), around 90% of the respondents were found to be pro-vaccine, based on a dichotomized 5-point Likert response on the statement 'If a vaccine is available against a certain disease, vaccination is mostly a good method to protect individuals against this disease'. Likely based on commonly rumored measles vaccine side-effects, 4.6% thought measles vaccine could cause autism. Also, 8.5% indicated chronic fatigue syndrome and 11.7% an overloaded immune system as possible side-effects. On the other hand, 58% perceived measles as a severe to very severe disease. About half of the respondents indicated they 'do not question vaccination, it's something I do when it is offered to me'. About 28% agreed with the statement 'The vaccine-related decisions of friends, other parents and/or family affect my own decision'. Henceforth, we will use the term 'relier' to refer to the individuals agreeing with this statement (see also Brunson et al. [33]). Conversely, we refer to 61% of the respondents agreeing with the statement 'I deliberately weigh the advantages and disadvantages of a vaccine against the disadvantages of the disease, before making a decision', as 'thinker'. With respect to the household structure, our sample consisted of 16% single parents, 26% singles without children, 15% living together without children and 43% living together with one or more children. We found no significant associations between risk perception and vaccine preferences.

The summary of background characteristics from our DCE sample of 1200 individuals in Table 1 shows that, in terms of educational attainment, individuals with no schooling or only primary schooling were not reached. Hence, our results are only representative for a subpopulation in South Africa that attained at least secondary school. With respect to ethnicity, we performed additional analyses using 100 sub-datasets to meet the population statistics, as explained in the methods section.

For the ethnicity-adjusted analysis, Figure 2 displays the relative importance of the attributes by means of the normalized logworth values, i.e. the logworth values relative to the most important attribute, which is vaccine effectiveness. We found all six attributes to be significantly associated with vaccine-related decisions. Vaccine effectiveness is followed by accessibility and population coverage which both had a relative importance of about 60% compared to vaccine effectiveness. Note also that in some of the 100 analyses the rank order of accessibility and population coverage switched, hence the large overlap in confidence intervals. Furthermore, vaccine-preventable burden of disease ranked fourth, with a relative importance of about 40%. Local vaccination coverage and frequency of mild VRSE were found to be less decisive, with a relative importance of 25% or less.

Covariate interactions were estimated with the full survey data for both the adult and child group (both N=600). The model results are shown in Figure 3 and Tables 3 and 4, and are comparable with those of the ethnicity-adjusted analysis. We elaborate on the main findings in the next paragraphs and the discussion section.

Adult model

For respondents in the adult group, i.e. for individuals making vaccine choices for themselves, all six attributes were significantly associated with vaccine-related decisions (p-value <0.05) (Figure 3). Vaccine effectiveness was by far the most important attribute, followed by population coverage and burden of disease, which were ranked as about half as important. Accessibility and local coverage were also influential attributes, although to a lesser extent (26.5% and 16.2%, respectively). Mild VRSE was found to be relatively unimportant as it ranked last, after several covariate interaction terms, with a relative importance of 7.4%. We observed substantial preference heterogeneity demonstrated by significant covariate interactions with accessibility, burden of disease, population coverage and mild VRSE. We elaborate on preference heterogeneity further in this section. In Table 3, we display the estimates for the adult model, which represent marginal utilities assigned to the different (combinations of) attribute levels. For example, a vaccine protecting 90% of vaccinated individuals (as opposed to 50%) increased vaccine utility by 0.906. Note that the coverage attributes are treated in a linear way. For example, the marginal utility of a population coverage of 50% was 5 x 0.113 = 0.565. Our analysis indicated that the most favored vaccine profile was a vaccine with 90% vaccine effectiveness, 100% population and local

coverage, protecting against a common & severe disease, that was free & accessible and with mild VRSE rarely occurring (yielding a total utility of 3.176). Note that the estimates of the coverage attributes were positive, suggesting that individuals were more inclined to opt for vaccination if more people were vaccinated. Note also that for the burden of disease attribute, which was expressed in terms of susceptibility and severity, the marginal utilities of a vaccine protecting against a rare & severe disease and a common & severe disease were positive and those of a vaccine protecting against a rare & mild disease and a common & mild disease negative. This implies that respondents assigned more weight to severity of disease than to susceptibility.

Regarding the observed preference heterogeneity, we found the most significant covariate interaction between accessibility and province (Table 3). Respondents in some provinces (Western Cape, Northern Cape and North West) were more sensitive to accessibility characteristics of vaccines than the average respondent. They attached a relatively lower value to a vaccine that requires patient co-payment and a prescription, and a relatively higher value to a vaccine that is free & accessible.

Figure 4 visualizes three other significant covariate interactions. Respondents selecting the internet as a source of information regarding infectious diseases and prevention seemed more sensible in their choice between preventing a rare & mild versus a common & mild disease, indicating more often their preference for the latter than other respondents (Figure 4a). Preference heterogeneity based on internet use for information gathering was also observed for mild VRSE (Figure 4b). Individuals not using the internet as a source of information hardly attached any value to mild VRSE as opposed to those who did use the internet. The significant covariate interaction with 'relier' relates to the dichotomized response (agree vs. disagree) on the statement 'The vaccine-related decisions of friends, other parents and/or family affect my own decision' (Figure 4c). People who disagreed with the statement were less sensitive to the description of the burden of disease. On the other hand, individuals who did agree with the statement attached relatively more value to a vaccine protecting against a common & severe disease. Also, they were less inclined to opt for vaccination if the disease against which the vaccine protects was common & mild.

The last significant covariate interaction appeared between occupational status and population coverage (Table 3). The positive estimate of 0.042 for individuals that were unemployed implied that they attached

a relatively higher value to population coverage and hence were more prone to peer influence or social norms in their vaccine-related decisions.

Child model

When respondents completed the questionnaire for vaccines that would be administered to their youngest child, again all six attributes influenced the vaccine decision-making significantly (Figure 3). Vaccine effectiveness was the key attribute, followed by population coverage, burden of disease and local coverage, with relative importance levels of 50.5%, 42.9% and 24.1% compared to vaccine effectiveness, respectively. Accessibility and frequency of mild VRSE were least valued at 14.8% and 6.6%, respectively. Also, we observed preference heterogeneity through three significant covariate interactions with vaccine attributes.

Table 4 shows that the mean utility ranking of the attribute levels of 'burden of disease' is more rational in the child model than in the adult model: in the child model a vaccine protecting against a common & mild disease was generally preferred to a vaccine protecting against a rare & mild disease.

Figure 5 shows significant interactions with burden of disease. Single parents attached a higher value to burden of disease: they valued a vaccine protecting against a rare & mild disease and against a common & mild disease less than respondents of a two-parent household (Figure 5a). Also, single parents attached more value to a vaccine protecting against a rare & severe disease than respondents of a two-parent household.

The significant interaction with being a 'thinker' involves the dichotomized response (agree vs. disagree) on the statement: 'I deliberately weigh the advantages and disadvantages of a vaccine against the disadvantages of the disease, before making a decision' (Figure 5b). Individuals agreeing with the 'thinker' statement attached a higher absolute value to the different levels of the burden of disease attribute. However, they valued a vaccine protecting against common & mild disease worse than a vaccine protecting against a rare & mild disease, which seemed somewhat counterintuitive.

Lastly, we discovered preference heterogeneity based on religion and the accessibility attribute. In general, free & available vaccines are preferred, and this preference is more outspoken for Buddhist, Jewish and non-religious people than for Christian and Muslim respondents (Table 4).

Discussion

Four vaccination behavior profiles were recently distinguished by a WHO SAGE Working Group on Vaccine Safety: active demand, passive acceptance, vaccine hesitancy and vaccine refusal. They also defined vaccine hesitancy as a 'delay in acceptance or refusal of vaccination despite availability of vaccination services'. In essence, the vaccine hesitancy continuum is anywhere between those who accept all vaccines on time and those who refuse any vaccine. In order to increase or maintain high vaccination coverage it is therefore pivotal to focus on the population in this hesitancy continuum and develop context, community and vaccine specific strategies [34, 35].

By means of our DCE, we gathered insights in the vaccine decision-making process among a sample of relatively higher educated and slightly younger adults in South Africa. More specifically, we found vaccine effectiveness to be the key element in vaccine-related decision-making. Population coverage, as well as burden of disease, were also highly important, followed by local coverage and accessibility. The frequency of mild VRSE was relatively unimportant. These conclusions hold for both the adult and child group. We did not observe large differences between the two groups except for a few covariate interactions. The attribute importance ranking from the analysis of the ethnicity-adjusted samples tells a similar story. However, accessibility seemed more important in this analysis, which might be due to the fact that Black Africans are more represented in the latter analysis and/or because covariate interactions were not considered.

The marginal utilities of population and local coverage are positive, with the largest utility for population coverage. This means that individuals were more likely to accept a vaccination if more individuals have had already done so. As such, peer effects and social norms dominated vaccine decision-making rather than free-rider motives. This is similar to results from a Belgian [19], an Australian [15], and a US [21] survey.

For policymakers, these results are highly relevant and provide the opportunity to stimulate vaccination coverage. Vaccination campaigns can cause a positive dynamic: a one-time increase in vaccination uptake will have a larger impact through peer influence. However, this dynamic also works in the other direction: a sudden (exogenous) fall in vaccination coverage can also trigger a further decline in vaccine uptake, causing vaccination no longer to be the social norm. Communication about coverage levels on both the population and the local level is however essential for this dynamic to take place. Note that this social norm effect is opposite to the common hypothesis of free-riding on herd immunity [19]. Behavioral models capturing vaccine decisions in South Africa should consider social norms instead of free-riding behavior. A recent systematic review on vaccine hesitancy confirms social norms to be an important determinant in vaccine decision-making [36].

Timely and accurate information about vaccine effectiveness and burden of disease can contribute to increasing vaccination coverage. Measles vaccines, for instance, are highly efficacious vaccines [9] and it is crucial to emphasize this in vaccine communications by health care workers, health agencies and policymakers. With respect to burden of disease, it is important to stress the severity and susceptibility of vaccine-preventable diseases and co-infections. Especially so in the South African setting where the prevalence of HIV is amongst the highest in the world [10].

Looking at the attribute importance from the analysis of the ethnicity-adjusted samples, we observed relatively high values for the accessibility of the vaccine (Figure 2). We found that it is essential to have vaccines available for free and without a prescription. Currently, most vaccines are available at no cost in government health care facilities. Some vaccines, however, are only available in private health care facilities and are not cheap, (e.g., against chickenpox and hepatitis A, and the MMR vaccine). See [37] for more information about the South African public and private immunization schedules. It is essential to keep vaccines conveniently available at an affordable price. Accessibility was also an important attribute in other studies [15, 17, 18, 20, 21], although a different specification of the attribute levels (out-of-pocket cost, cost per visit, etc.) was used in these studies.

We tested covariate interactions with vaccine attributes in a systematic way and found only one significant interaction with religion: vaccine accessibility in the child model (Figure 5a). Since measles vaccine is already offered free of charge in South Africa, we think policymakers should look beyond

religion to explain low uptake in certain areas and provide accurate and timely information on the attributes that matter most. Moreover, they should target hesitant people, known to be looking for information about vaccines and infectious diseases. If questions remain in hesitant groups, they could receive incorrect or biased information from the internet, social media etc. [38].

The limited importance of perceived VRSE as observed in this study is peculiar, given that VRSE was the most important attribute in a recent DCE about vaccination behavior in Belgium [19]. Nevertheless, the specification of VRSE in the latter study did not control for VRSE severity, i.e. it was only specified in terms of frequency. In the current study we explicitly specified that all severe VRSE would be exceptional as vaccines for which severe VRSE can occur frequently, will and should not be licensed.

Study limitations

DCE attributes and attribute levels were selected from a previous DCE [19], whereas DCE guidelines [39, 40] recommend the use of qualitative methods. Even though these attributes were not tailor-made for a specific population, we were able to capture the relative importance our sample attached to six generally accepted vaccine characteristics. This provides the opportunity for policymakers to focus on a select number of vaccine characteristics in information campaigns. Because the aim of our study was to assess the relative importance of the vaccine attributes, we decided not to include an opt-out option. An opt-out option could, nevertheless, be interesting in future research to additionally retrieve trade-offs on vaccinating versus not vaccinating. Our sample was unable to capture the educational attainment level of the South African population. This is due to our decision to collect the data through an online tool and the fact that we did not specify pre-defined quota on educational attainment. Regarding ethnicity, our sample did not fully match the population criteria. However, we investigated the main effects through a bootstrap procedure generating attribute importance rankings with confidence intervals for adjusted samples that matched the census population. With respect to age groups, we matched the population distribution fairly well with the exception of the oldest age group. This could be due to the use of an online panel and our pre-defined sample quota of 50% having at least one child below the age of 18 years.

Conclusion

We performed a discrete choice experiment to gain insights into vaccination behavior in South Africa. We found vaccine effectiveness, vaccination coverage, accessibility and burden of disease to be important attributes. Moreover, we observed positive utility estimates for vaccination coverage, indicating peer influence and social norms to be vital in vaccine decision-making, conditional on people knowing about positive vaccination behavior by others in their circle of acquaintances or in the population at large. Policymakers and health care workers should emphasize the effectiveness of vaccines, stress the burden of vaccine preventable diseases and encourage people to discuss their positive vaccination experiences with their acquaintances. If coverage is sufficiently high, (social) media campaigns reporting coverage are important to further increase and maintain coverage and to reach herd immunity thresholds. These campaigns can also be beneficial if they provide information on the burden of disease (including information on burden of disease in counterfactual scenarios, if coverage were to decline). Such campaigns could also be well-timed around outbreaks (stressing the severity and susceptibility due to low coverage). Moreover, South African policymakers should keep vaccines free of charge and available in all government clinics (as already the case for most vaccines). Cost-effectiveness analyses should determine whether to provide additional vaccines through the public health system.

Acknowledgements

FV, PB and LW acknowledge support of the Antwerp Study Centre for Infectious Diseases (ASCID) at the University of Antwerp. PB, FV, LW and RK acknowledge support by the Research Foundation Flanders (research project no. G043815N and a postdoctoral fellowship (RK)). Funding for the data collection was provided by the Global Minds initiative at the University of Antwerp. We thank all respondents who participated in the study. We also thank Villyen Motaze for providing background information with respect to the South African immunization programme, and two anonymous referees for providing constructive comments that substantially improved our manuscript. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript. Conflicts of interest: none.

All authors attest they meet the ICMJE criteria for authorship.

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Figures and tables

Fig 1. Example of a choice set with three varying and three constant vaccine attributes.

Protects 90% of vaccinated persons	Protects 50% of vaccinated persons
The disease, against which the vaccine protects is common and often mild: hospitalisation is exceptional and the disease is not life-threatening.	The disease, against which the vaccine protects is common and often mild: hospitalisation is exceptional and the disease is not life-threatening.
Mild side-effects commonly occur and severe side-effects are highly unlikely	Mild side-effects commonly occur and severe side-effects are highly unlikely
The vaccine is not reimbursed and is only available with a prescription	The vaccine is provided for free and is directly available at the vaccinator (GP, well-baby clinic, school- or occupational physician)
90% of your acquaintances (friends and family) is vaccinated	60% of your acquaintances (friends and family) is vaccinated
60% of the general population is vaccinated	60% of the general population is vaccinated
○	○

Fig 2. Importance of the main effects of the six attributes relative to the most important attribute 'vaccine effectiveness'. Bars represent the mean normalized logworth values with 95% confidence intervals for 100 subsamples of 700 respondents adjusted for ethnicity levels.

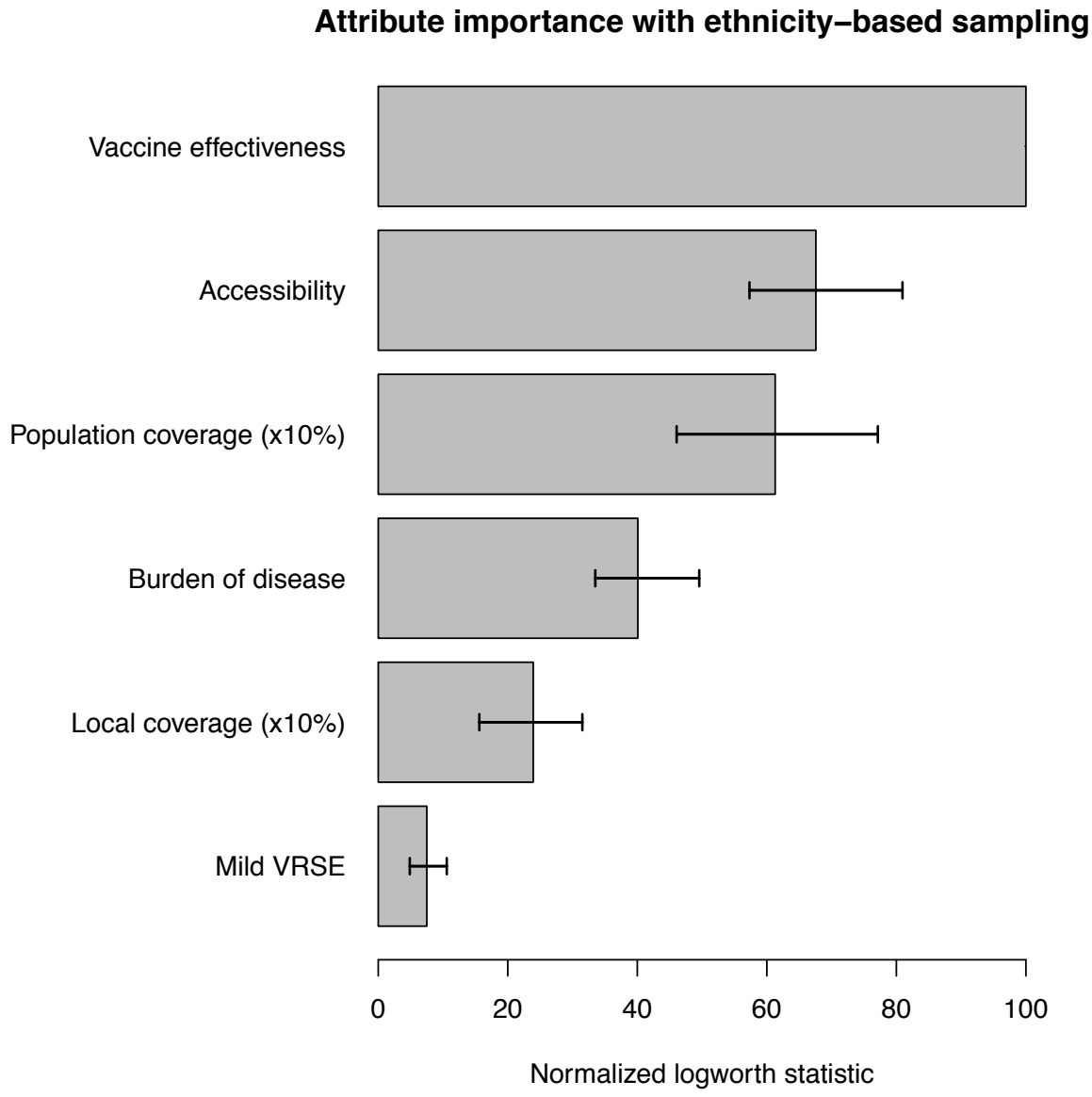

Fig 3. Importance of all statistically significant main and interaction effects (p-value < 0.05) relative to the most important attribute 'vaccine effectiveness'.

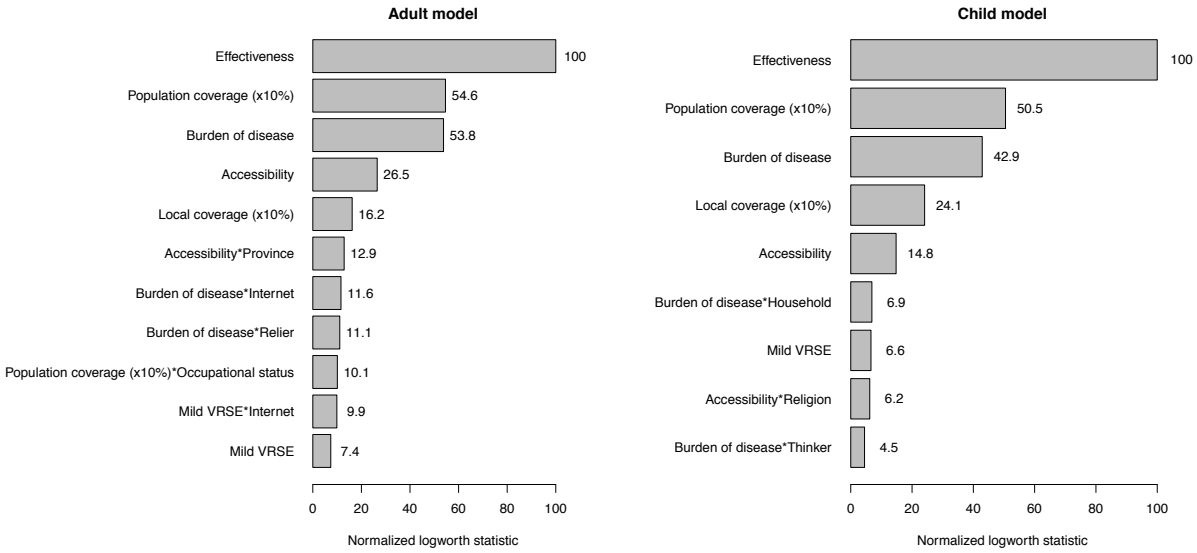

Fig 4. Marginal utilities for the significant covariate interaction terms in the adult model.

Fig 4(a). Covariate interaction between burden of disease and internet as a source of information.

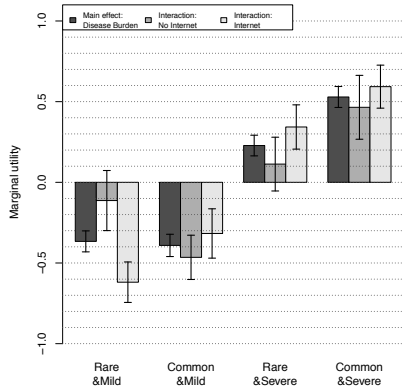

Fig 4(b). Covariate interaction between Mild VRSE and internet as a source of information.

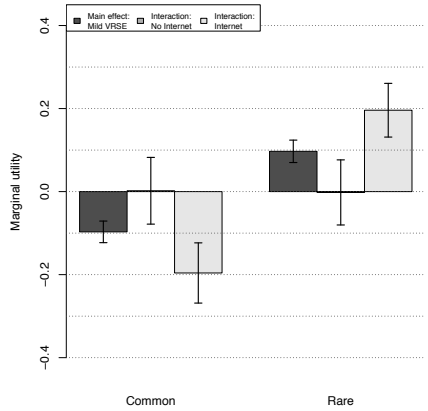

Fig 4(c). Covariate interaction between burden of disease and agree/disagree with the ‘relier’ statement.

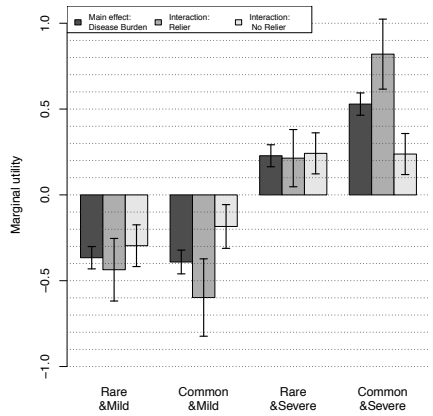

Fig 5. Marginal utilities for the significant covariate interaction terms in the child model.

Fig 5(a). Covariate interaction between burden of disease and household composition.

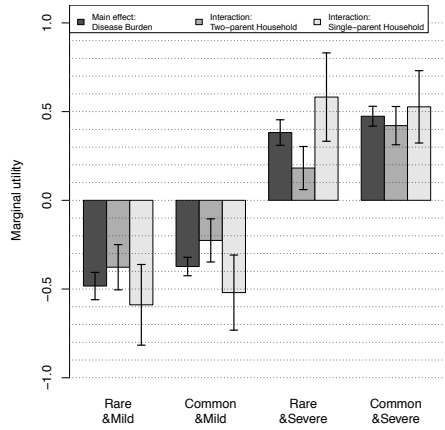

Fig 5(b). Covariate interaction between burden of disease and agree/disagree with the ‘thinker’ statement.

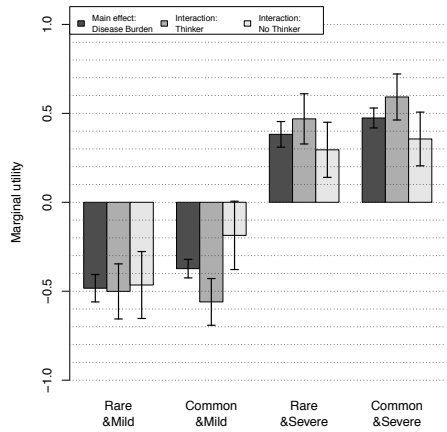

Table 1. Sample characteristics and national statistics for South Africa from Stats SA Community survey 2016 [23]. (* age group "18-34 years" from the survey is compared with age group "20-34 years" from Stats SA.)

(* age group "18-34 years" from the survey is compared with age group "20-34 years" from Stats SA.)

Characteristic	**Adult group (%)**	**Child group (%)**	**Sample (%)**	**South African population (%)**	**Pre-defined quota (%)**
Gender					
Male	52.0	44.8	48.4	49.0	50.0
Female	48.0	55.2	51.6	51.0	50.0
Age group					
18-34 (*)	55.6	42.0	48.8	44.5	≥30.0
35-49	21.7	49.2	35.5	29.3	≥30.0
50+	22.8	8.8	15.8	26.2	≥20.0
Educational attainment					
No schooling	0.2	0	0.1	6.0	
Primary education	0.3	0	0.2	59.3	
Secondary education	33.3	28.5	30.9	31.4	NA
Bachelor's degree	62.2	65.3	63.8	3.3	
Other	4.0	6.2	5.1	NA	
Ethnicity					
Black African	48.8	52.3	50.6	80.7	>50.0
Coloured	5.7	8.8	7.3	8.7	>4.0
Indian/Asian	4.0	3.5	3.8	2.5	>1.0
White	40.8	33.7	37.3	8.1	>4.0
Other	0.7	1.7	1.2	NA	NA
Province					
Guateng	47.0	45.7	46.4	24.1	
North West	2.7	3.8	3.3	6.7	
Limpopo	2.0	2.8	2.4	10.4	
Mpumalanga	5.0	4.5	4.8	7.8	
KwaZulu-Natal	11.8	15.0	13.4	19.9	NA
Eastern Cape	8.3	6.5	7.4	12.6	
Western Cape	18.3	16.0	17.2	11.3	
Northern Cape	1.8	1.3	1.6	2.1	
Free State	3.0	4.2	3.6	5.1	
Sample size	**N=600**	**N=600**	**N=1200**		

Table 2. DCE attributes and levels.

Attribute	**Level description**
1. Vaccine effectiveness	a) Protects **50%** of vaccinated persons b) Protects **90%** of vaccinated persons
2. Burden of disease	a) The disease, against which the vaccine protects is **rare** and often **mild**: hospitalisation is exceptional and the disease is not life-threatening b) The disease, against which the vaccine protects is **rare** and often **severe**: often with hospitalisation and the disease is life-threatening c) The disease, against which the vaccine protects is **common** and often **mild**: hospitalisation is exceptional and the disease is not life-threatening d) The disease, against which the vaccine protects is **common** and often **severe**: often with hospitalisation and the disease is life-threatening
3. VRSE	a) Mild side-effects **commonly** occur and severe side-effects are highly unlikely b) Mild side-effects **rarely** occur and severe side-effects are highly unlikely
4. Accessibility	a) The vaccine is provided for **free** and **is directly available at the vaccinator** (GP, well-baby clinic, school- or occupational physician) b) The vaccine is **not reimbursed** and is **only available with a prescription**
5. Local coverage	a) **30%** of your acquaintances (friends and family) is vaccinated b) **60%** of your acquaintances (friends and family) is vaccinated c) **90%** of your acquaintances (friends and family) is vaccinated
6. Population coverage	a) **30%** of the population in general is vaccinated b) **60%** of the population in general is vaccinated c) **90%** of the population in general is vaccinated

Table 3. Panel mixed logit model estimates of the Adult model: mean and standard deviation (std dev) and significance of the attribute effects obtained from likelihood ratio (LR) tests with a specified number of degrees of freedom (DF).

Term	Mean estimate (std dev; subject std dev)	LR Chi-square	DF	P-value
Vaccine effectiveness				
50%	-0.453 (0.031; 0.121)	141.246	1	< 0.0001
90%	0.453 (0.030; 0.121)			
Population coverage (x10%)	0.113 (0.013; 0.070)	75.302	1	< 0.0001
Burden of disease				
Rare & mild	-0.366 (0.065; 0.096)	82.841	3	< 0.0001
Common & mild	-0.391 (0.069; 0.084)			
Rare & severe	0.228 (0.064; 0.069)			
Common & severe	0.529 (0.065; 0.078)			
Accessibility				
Co-payment & prescription	-0.347 (0.057; 0.090)	34.766	1	< 0.0001
Free & accessible	0.347 (0.041; 0.084)			
Local coverage (x10%)	0.062 (0.012; 0.081)	20.241	1	< 0.0001
Accessibility*Province				
Co-payment & prescription*Eastern Cape	0.385 (0.107; 0.065)	32.510	8	< 0.0001
Co-payment & prescription*Free State	0.044 (0.135; 0.066)			
Co-payment & prescription*Guateng	0.042 (0.069; 0.087)			
Co-payment & prescription*KwaZulu-Natal	0.134 (0.064; 0.060)			
Co-payment & prescription*Limpopo	0.036 (0.255; 0.095)			
Co-payment & prescription*Mpumalanga	0.333 (0.104; 0.069)			
Co-payment & prescription*North West	-0.394 (0.136; 0.081)			
Co-payment & prescription*Northern Cape	-0.303 (0.167; 0.090)			
Co-payment & prescription*Western Cape	-0.277 (0.057; 0.075)			
Free & available*Eastern Cape	-0.385 (0.095; 0.064)			
Free & available*Free State	-0.044 (0.162; 0.070)			
Free & available*Guateng	-0.042 (0.056; 0.083)			
Free & available*KwaZulu-Natal	-0.134 (0.082; 0.071)			
Free & available*Limpopo	-0.036 (0.226; 0.097)			
Free & available*Mpumalanga	-0.333 (0.139; 0.069)			
Free & available*North West	0.394 (0.245; 0.069)			
Free & available*Northern Cape	0.303 (0.192; 0.086)			
Free & available*Western Cape	0.277 (0.079; 0.080)			
Burden of disease*Internet				
Rare & mild*not selected	0.253 (0.054; 0.073)	19.649	3	0.0002
Rare & mild*internet selected	-0.253 (0.046; 0.071)			
Common & mild*not selected	-0.074 (0.056; 0.072)			
Common & mild*internet selected	0.074 (0.055; 0.067)			
Rare & severe*not selected	-0.115 (0.059; 0.058)			
Rare & severe*internet selected	0.115 (0.063; 0.061)			
Common & severe*not selected	-0.064 (0.053; 0.065)			
Common & severe*internet selected	0.064 (0.042; 0.061)			
Burden of disease*Relier				
Rare & mild*disagree	0.070 (0.067; 0.106)	18.929	3	0.0003
Rare & mild*agree	-0.070 (0.055; 0.068)			
Common & mild*disagree	0.207 (0.073; 0.072)			
Common & mild*agree	-0.207 (0.063; 0.078)			
Rare & severe*disagree	0.014 (0.055; 0.071)			
Rare & severe*agree	-0.014 (0.051; 0.073)			
Common & severe*disagree	-0.291 (0.060; 0.067)			
Common & severe*agree	0.291 (0.058; 0.065)			
Population coverage (x10%)*Occupational status				
Population coverage (x10%)*not working	0.042 (0.013; 0.068)	11.703	1	0.0006
Population coverage (x10%)*working	-0.042 (0.012; 0.065)			
Mild VRSE*Internet				
Common*not selected	0.099 (0.022; 0.058)	11.417	1	0.0007
Common*internet selected	-0.099 (0.024; 0.053)			
Rare*not selected	-0.099 (0.024; 0.057)			
Rare*internet selected	0.099 (0.023; 0.055)			
Mild VRSE				
Common	-0.097 (0.026; 0.057)	8.056	1	0.0045
Rare	0.097 (0.027; 0.059)			

Note: Mean estimates corresponding to the last level of an attribute are calculated as minus the sum of the estimates for the other levels of the attribute.

Table 4. Panel mixed logit model estimates of the Child model: mean and standard deviation (std dev) and significance of the attribute effects obtained from likelihood ratio (LR) tests with a specified number of degrees of freedom (DF).

Term	Mean estimate (std dev; subject std dev)	LR Chi-square	DF	P-value
Vaccine effectiveness				
50%	-0.583 (0.030; 0.084)	245.794	1	< 0.0001
90%	0.583 (0.030; 0.091)			
Population coverage (x10%)	0.129 (0.010; 0.074)	121.966	1	< 0.0001
Burden of disease				
Rare & mild	-0.483 (0.077; 0.113)	112.268	3	< 0.0001
Common & mild	-0.373 (0.052; 0.094)			
Rare & severe	0.382 (0.072; 0.071)			
Common & severe	0.474 (0.056; 0.075)			
Local coverage (x10%)	0.098 (0.011; 0.070)	56.194	1	< 0.0001
Accessibility				
Co-payment & prescription	-0.681 (0.119; 0.148)	33.361	1	< 0.0001
Free & accessible	0.681 (0.074; 0.148)			
Burden of disease*Household (HH)				
Rare & mild*two parents HH	0.106 (0.071; 0.087)	20.013	3	0.0002
Rare & mild*one parent HH	-0.106 (0.059; 0.085)			
Common & mild*two parents HH	0.147 (0.053; 0.091)			
Common & mild*one parent HH	-0.147 (0.059; 0.098)			
Rare & severe*two parents HH	-0.200 (0.069; 0.066)			
Rare & severe*one parent HH	0.200 (0.065; 0.068)			
Common & severe*two parents HH	-0.053 (0.053; 0.058)			
Common & severe*one parent HH	0.053 (0.059; 0.075)			
Mild VRSE				
Common	-0.116 (0.028; 0.065)	13.548	1	0.0002
Rare	0.116 (0.027; 0.057)			
Accessibility*Religion				
Co-payment & prescription*no answer	0.864 (0.750; 0.071)	26.506	7	0.0004
Co-payment & prescription*not religious	-0.268 (0.196; 0.118)			
Co-payment & prescription*Buddhism	-0.936 (0.756; 0.101)			
Co-payment & prescription*Christian	0.304 (0.125; 0.157)			
Co-payment & prescription*Hindu	0.010 (0.294; 0.088)			
Co-payment & prescription*Judaism	-0.909 (0.478; 0.120)			
Co-payment & prescription*Muslim	0.089 (0.230; 0.074)			
Co-payment & prescription*other	0.846 (0.432; 0.085)			
Free & available*no answer	-0.864 (0.396; 0.075)			
Free & available*not religious	0.268 (0.185; 0.114)			
Free & available*Buddhism	0.936 (0.716; 0.108)			
Free & available*Christian	-0.304 (0.076; 0.149)			
Free & available*Hindu	-0.010 (0.354; 0.081)			
Free & available*Judaism	0.909 (0.486; 0.108)			
Free & available*Muslim	-0.089 (0.254; 0.074)			
Free & available*other	-0.846 (0.417; 0.101)			
Burden of disease*Thinker				
Rare & mild*agree	-0.018 (0.058; 0.079)	13.642	3	0.0034
Rare & mild*disagree	0.018 (0.043; 0.079)			
Common & mild*agree	-0.187 (0.050; 0.072)			
Common & mild*disagree	0.187 (0.045; 0.065)			
Rare & severe*agree	0.087 (0.063; 0.058)			
Rare & severe*disagree	-0.087 (0.046; 0.059)			
Common & severe*agree	0.118 (0.046; 0.063)			
Common & severe*disagree	-0.118 (0.040; 0.061)			

Note: Mean estimates corresponding to the last level of an attribute are calculated as minus the sum of the estimates for the other levels of the attribute.

Drivers of Vaccine Decision-Making in South Africa: a Discrete Choice Experiment

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Appendix A. Bayesian D-optimal partial profile design

The design of the DCE, shown in Table A.1, includes five surveys of 10 choice sets with two alternative vaccination programs. The choice sets in each survey were assigned in a random order to the respondents. Each survey was completed by about 120 respondents in the adult group and 120 respondents in the child group. The choice sets are described by six attributes, three of which have varying levels and the remaining three constant levels. The levels of the varying attributes are indicated in yellow. The constant attributes are shown to present vaccine profiles in full as well as to enable estimating all two-way interactions between any of the six attributes, and 'vaccine effectiveness', 'mild VRSE' and 'accessibility'. In each survey each attribute is varying in five choice sets and constant in five choice sets.

Table A.1 The Bayesian D-optimal partial profile design

Survey id	Choice set	Vaccine effectiveness	Burden of disease	Mild VRSE	Accessibility	Local coverage	Population coverage
1	1	50%	Rare & mild	Rare	Co-payment & prescription	60%	30%
1	1	50%	Rare & mild	Frequent	Co-payment & prescription	30%	90%
1	2	90%	Rare & mild	Frequent	Co-payment & prescription	60%	60%
1	2	90%	Rare & mild	Rare	Free & accessible	90%	60%
1	3	90%	Common & severe	Rare	Free & accessible	30%	30%

1	3	90%	Rare & severe	Rare	Free & accessible	60%	90%
1	4	50%	Rare & severe	Frequent	Co-payment & prescription	60%	90%
1	4	50%	Rare & mild	Frequent	Free & accessible	60%	30%
1	5	50%	Rare & severe	Frequent	Free & accessible	60%	90%
1	5	50%	Rare & mild	Rare	Co-payment & prescription	60%	90%
1	6	90%	Rare & mild	Frequent	Co-payment & prescription	30%	30%
1	6	50%	Rare & mild	Frequent	Free & accessible	30%	60%
1	7	90%	Common & mild	Frequent	Co-payment & prescription	90%	60%
1	7	50%	Common & mild	Frequent	Free & accessible	60%	60%
1	8	90%	Rare & severe	Frequent	Free & accessible	90%	90%
1	8	50%	Rare & severe	Rare	Free & accessible	90%	60%
1	9	50%	Common & severe	Rare	Co-payment & prescription	90%	30%
1	9	90%	Common & mild	Rare	Co-payment & prescription	60%	30%
1	10	50%	Common & severe	Rare	Co-payment & prescription	90%	90%
1	10	90%	Rare & mild	Frequent	Co-payment & prescription	90%	90%
2	1	50%	Common & mild	Frequent	Co-payment & prescription	60%	60%
2	1	50%	Common & mild	Frequent	Free & accessible	30%	30%
2	2	90%	Common & severe	Rare	Free & accessible	60%	90%
2	2	90%	Common & severe	Frequent	Co-payment & prescription	30%	90%
2	3	50%	Rare & severe	Frequent	Co-payment & prescription	30%	60%
2	3	50%	Common & mild	Frequent	Co-payment & prescription	60%	90%
2	4	90%	Rare & mild	Rare	Free & accessible	30%	90%
2	4	90%	Rare & severe	Frequent	Free & accessible	30%	60%
2	5	90%	Common & severe	Frequent	Co-payment & prescription	90%	30%

2	5	90%	Rare & mild	Rare	Free & accessible	90%	30%
2	6	50%	Rare & severe	Rare	Free & accessible	60%	90%
2	6	90%	Rare & severe	Rare	Co-payment & prescription	60%	60%
2	7	90%	Common & severe	Frequent	Co-payment & prescription	60%	60%
2	7	50%	Common & severe	Rare	Co-payment & prescription	60%	30%
2	8	90%	Rare & mild	Frequent	Free & accessible	30%	60%
2	8	50%	Rare & mild	Rare	Free & accessible	90%	60%
2	9	50%	Common & severe	Frequent	Co-payment & prescription	90%	60%
2	9	90%	Rare & mild	Frequent	Co-payment & prescription	60%	60%
2	10	90%	Rare & severe	Rare	Co-payment & prescription	30%	60%
2	10	50%	Common & severe	Rare	Free & accessible	30%	60%
3	1	50%	Common & mild	Rare	Free & accessible	60%	90%
3	1	50%	Common & mild	Rare	Co-payment & prescription	30%	30%
3	2	90%	Rare & severe	Frequent	Free & accessible	30%	90%
3	2	90%	Rare & severe	Rare	Free & accessible	60%	30%
3	3	90%	Rare & severe	Rare	Co-payment & prescription	90%	90%
3	3	90%	Common & mild	Rare	Free & accessible	90%	30%
3	4	90%	Rare & severe	Rare	Free & accessible	30%	30%
3	4	90%	Common & severe	Frequent	Free & accessible	90%	30%
3	5	50%	Rare & mild	Rare	Co-payment & prescription	90%	60%
3	5	50%	Common & mild	Frequent	Free & accessible	90%	60%
3	6	90%	Rare & severe	Frequent	Co-payment & prescription	30%	90%
3	6	50%	Rare & severe	Frequent	Free & accessible	90%	90%
3	7	90%	Common & severe	Frequent	Co-payment & prescription	30%	90%

3	7	50%	Common & severe	Rare	Co-payment & prescription	30%	60%
3	8	90%	Common & mild	Frequent	Co-payment & prescription	30%	30%
3	8	50%	Common & mild	Rare	Free & accessible	30%	30%
3	9	90%	Rare & mild	Frequent	Free & accessible	60%	90%
3	9	50%	Rare & severe	Frequent	Free & accessible	60%	30%
3	10	50%	Rare & severe	Rare	Co-payment & prescription	30%	30%
3	10	90%	Rare & mild	Rare	Co-payment & prescription	90%	30%
4	1	50%	Rare & mild	Rare	Co-payment & prescription	30%	90%
4	1	50%	Rare & mild	Frequent	Co-payment & prescription	60%	30%
4	2	90%	Common & severe	Frequent	Free & accessible	30%	30%
4	2	90%	Common & severe	Rare	Co-payment & prescription	30%	60%
4	3	90%	Rare & mild	Rare	Free & accessible	60%	60%
4	3	90%	Common & mild	Rare	Free & accessible	90%	90%
4	4	50%	Rare & mild	Frequent	Free & accessible	90%	60%
4	4	50%	Common & mild	Frequent	Co-payment & prescription	30%	60%
4	5	90%	Rare & severe	Frequent	Free & accessible	90%	30%
4	5	90%	Common & mild	Rare	Co-payment & prescription	90%	30%
4	6	50%	Common & severe	Frequent	Free & accessible	60%	90%
4	6	90%	Common & severe	Frequent	Co-payment & prescription	60%	30%
4	7	90%	Rare & mild	Rare	Co-payment & prescription	90%	90%
4	7	50%	Rare & mild	Rare	Free & accessible	60%	90%
4	8	90%	Common & mild	Frequent	Free & accessible	60%	90%
4	8	50%	Common & mild	Rare	Free & accessible	30%	90%
4	9	50%	Common & severe	Frequent	Co-payment & prescription	30%	90%

4	9	90%	Common & mild	Frequent	Co-payment & prescription	30%	60%
4	10	50%	Common & severe	Rare	Free & accessible	60%	60%
4	10	90%	Common & mild	Frequent	Free & accessible	60%	60%
5	1	90%	Common & severe	Rare	Co-payment & prescription	60%	90%
5	1	90%	Common & severe	Frequent	Free & accessible	60%	60%
5	2	50%	Rare & severe	Frequent	Co-payment & prescription	90%	60%
5	2	50%	Rare & severe	Rare	Free & accessible	30%	60%
5	3	90%	Rare & severe	Rare	Co-payment & prescription	90%	30%
5	3	90%	Common & mild	Rare	Co-payment & prescription	30%	90%
5	4	90%	Common & mild	Rare	Free & accessible	30%	60%
5	4	90%	Common & severe	Rare	Co-payment & prescription	30%	30%
5	5	50%	Common & severe	Frequent	Co-payment & prescription	60%	60%
5	5	50%	Common & mild	Rare	Co-payment & prescription	90%	60%
5	6	90%	Common & severe	Rare	Free & accessible	30%	60%
5	6	50%	Common & severe	Rare	Free & accessible	90%	30%
5	7	90%	Rare & mild	Frequent	Free & accessible	60%	30%
5	7	50%	Rare & mild	Frequent	Co-payment & prescription	30%	30%
5	8	90%	Rare & severe	Frequent	Co-payment & prescription	60%	30%
5	8	50%	Rare & severe	Rare	Co-payment & prescription	60%	60%
5	9	90%	Common & mild	Frequent	Co-payment & prescription	90%	90%
5	9	50%	Common & severe	Frequent	Free & accessible	90%	90%
5	10	50%	Common & severe	Rare	Free & accessible	90%	30%
5	10	90%	Rare & mild	Frequent	Free & accessible	90%	30%

Drivers of Vaccine Decision-Making in South Africa: a Discrete Choice Experiment

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Appendix B. Multivariate normal prior parameter distribution used to construct the Bayesian D-optimal partial profile design

To construct the Bayesian D-optimal partial profile design for the vaccination DCE shown in Appendix A, we used a multivariate normal prior distribution that reflects the prior beliefs about the unknown parameter values associated with the levels of the six attributes. Based on expert interviews and literature review, we ranked the six attributes in descending order of importance and specified mean parameter values and variances for the multivariate normal prior distribution.

Table B.1 shows the six attributes in descending order of expected importance. Based on the listed ranks, we specified prior mean utility values for the main effects of the attributes. The more important an attribute, the greater the a priori mean utility values specified for the main effects of that attribute. We had no preconception of people's preferences for both coverage attributes, which corresponds to specifying zero mean utility values. The preference direction for the levels of these attributes could be either increasing (i.e. higher coverage leads to more willingness to vaccinate) or decreasing. The a priori mean utility values associated with the levels of each attribute are symmetric around zero, and thus sum to zero. The latter is imposed by the effects-type coding used for the attribute levels, which means that the levels of the 2-level attributes 'vaccine effectiveness', 'mild VRSE' and 'accessibility' are coded as 1 and -1, the levels of the 3-level attributes 'local coverage' and 'population coverage' are coded as [1 0], [0 1] and [-1 -1] and the levels of the 4-level attribute 'burden of disease' are coded as [1 0 0], [0 1 0], [0 0 1] and [-1 -1 -1].

Table B.1 A priori order of importance of the main effects of the six attributes and conversion into mean utility values used in the multivariate normal prior distribution.

Rank	Attribute	Prior mean			
		Level a	Level b	Level c	Level d
1	Vaccine effectiveness	-0.8	0.8		
2	Burden of disease	-0.6	-0.2	0.2	0.6
3	Mild VRSE	-0.4	0.4		
4	Accessibility	-0.3	0.3		
5	Local coverage	0	0	0	
5	& Population coverage	0	0	0	

We also specified prior variances and covariances around the mean utility values for the attributes' main effects. We used values of 0.09 for all attribute levels, because this preserved the preference ordering for the levels of an attribute as much as possible. Following Kessels et al. [2008], we specified negative covariances of -0.045 for the 3-level attributes and -0.03 for the 4-level attribute so that we also obtained variances of 0.09 for the derived utility values associated with the last level of each attribute. We computed these covariances using prior correlations of -1/2 for the 3-level attributes and of -1/3 for the 4-level attribute.

In the absence of prior information for the interaction effects between an attribute, and 'vaccine effectiveness', 'VRSE' and 'accessibility', we specified zero mean utility values for these. For ease of computation, we also assumed zero prior variances around the utility values for the interaction effects, allowing for no uncertainty around these values. This implies that the prior parameter specification of the interaction effects corresponds to a local instead of a Bayesian approach.

Reference

Roselinde Kessels, Bradley Jones, Peter Goos, and Martina Vandebroek. Recommendations on the use of Bayesian optimal designs for choice experiments. *Quality and Reliability Engineering International*, 24(6):737-744, 2008.