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Imprecise Beliefs About Malaria Infection Risk and Vaccine Protection in Ghana

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Abstract

How do mothers respond when a new vaccine changes both the expected protection and how sure they feel about that protection? I study that question during Ghana's malaria vaccine rollout using a door-to-door survey of 4,383 mothers. For four simple vaccination situations, the current situation, no doses, one dose, and all doses, each mother reports a best guess of malaria risk and, if she is not fully sure, the lowest and highest risk she thinks is possible. I then relate those answers to malaria prevention, vaccine planning, appointment keeping, and timing recorded in child health booklets.

Three results stand out. First, many mothers give point estimates, but a sizeable minority report wide ranges, so uncertainty is real and unevenly distributed rather than a small survey artifact. Second, that uncertainty is strongly linked to planning, schedule tracking, and other forms of vaccine engagement, but much less clearly linked to booklet recorded timing. Third, when I compare adjacent dose transitions, perceived reductions in malaria risk matter more for behavior than reductions in uncertainty alone. The broad picture is therefore more consistent with uncertainty among engaged mothers than with pure confusion. The policy implication is straightforward: communication efforts are likely to work best when they help mothers who remain especially uncertain near the point of completing the schedule.

Keywords: malaria vaccine; subjective beliefs; belief imprecision; ambiguity; vaccine uptake; health behavior; Ghana

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1 Introduction

Malaria remains one of the most important sources of child mortality in sub Saharan Africa, and new vaccines change the informational problem facing mothers as much as they change the medical one (World Health Organization, 2023). A mother deciding whether to begin or complete a new vaccine schedule must form beliefs about protection, but in a novel rollout those beliefs are unlikely to be sharp point estimates. A mother may know her best guess about malaria risk with no doses, one dose, or all doses, yet still be genuinely uncertain about how much risk remains around that best guess. I refer to that uncertainty as *belief imprecision*: the gap between the lowest and highest infection probabilities a mother considers plausible. The central question of this paper is whether that margin of uncertainty carries behavioral content beyond the level of the best guess itself.

That question is substantively important in the malaria vaccine setting. Ghana introduced a malaria vaccine into its immunization program soon after the World Health Organization recommended broad pediatric use following phase 3 evidence of substantial protection against clinical malaria. In a new rollout, mothers are learning simultaneously about the existence of the vaccine, the multi-dose schedule, and the extent of protection that partial and complete vaccination can provide. Standard empirical work on vaccine demand typically compresses those beliefs into a single expected probability. Doing so rules out the possibility that two mothers with the same best guess may still behave differently because one feels much less certain than the other about what the vaccine will do. For questions of communication, appointment keeping, and follow-through, that omission may be consequential.

That distinction is especially relevant in a multi-dose vaccine environment. A mother may believe that malaria risk falls after one dose and falls further after all doses, yet remain unsure about how large each improvement really is or about how much protection remains uncertain even after completion. In that sense, the interval does not simply add statistical precision to a point estimate; it measures whether the mother experiences the vaccine as a known technology or as an uncertain one. For program design, those are different states of the world. A campaign aimed at correcting an overly pessimistic point belief is not the same as a campaign aimed at helping mothers interpret a new and unfamiliar protection technology whose effects they do not yet feel they can pin down.

I study this issue using a door-to-door survey of 4,383 eligible mothers in Ghana, interviewed in the catchment areas of selected frontline vaccination facilities. For each respondent, I elicit a best guess and lower and upper bounds on malaria infection risk under four scenarios: the current situation, no malaria vaccine doses, one dose, and all doses. The survey also measures two distinct behavioral margins. The first is *vaccination engagement*: planning to bring the child for the vaccine, not delaying or missing scheduled appointments, and using the card or booklet to track the schedule. The second is realized follow-through captured from child health booklets, including on-time dose receipt and dose completion for the subsample for whom booklet information is meaningful. This distinction turns out to matter for how the belief data should be interpreted.

Three findings organize the paper. *First, imprecision is common but unevenly distributed.* More than half of respondents report a zero range in any given scenario, but a substantial minority report positive intervals and the distribution of positive ranges is strongly right skewed. Central beliefs move substantially across scenarios in the expected direction, which indicates that respondents distinguish clearly between no dose, one dose, and all doses states. At the same time, the persistence of positive intervals shows that many mothers remain uncertain even when they can articulate a clear central belief about malaria risk.

Second, imprecision is much more closely related to engagement than to booklet verified timing. In the all doses scenario, reporting any positive belief range is associated with roughly 0.22 standard deviations higher vaccination engagement. The same pattern is much weaker for general preventive behavior and is close to zero for booklet based timing outcomes. Put plainly, mothers with uncertain beliefs appear more active in planning, tracking, and thinking about the vaccination process, but that does not translate directly into on-time completion in the booklet data. That wedge is informative because it separates the information seeking or planning stage from realized follow-through, which may also depend on supply conditions, household shocks, or other barriers beyond beliefs.

Third, perceived protection gains matter more than ambiguity reductions in the transition analysis. When I compare adjacent stages of the dose schedule, behavior responds more strongly to perceived reductions in infection risk than to reductions in the width of the belief interval. The implied α max-min summaries fall in an intermediate range, but the model comparison evidence is best read as descriptive guidance rather than decisive selection among decision rules. The most robust conclusion is narrower and more useful: mothers appear to respond primarily to how much lower they think malaria risk becomes, while the uncertainty margin plays a secondary, though still behaviorally meaningful, role.

These findings map naturally into three contributions. The first is *measurement*. I show that belief intervals are empirically relevant in a new vaccine setting and that they provide information that point beliefs alone miss. The second is *behavioral*. I distinguish between engagement with the vaccination process and realized timing, showing that imprecision is strongly related to the former but not clearly to the latter. The third is *conceptual*. The scenario and transition design lets me compare how perceived protection levels and perceived uncertainty reductions line up with behavior using the same elicited belief objects, while keeping the interpretation close to the institutional dose sequence that mothers actually face.

The policy reading of the results is also specific. If uncertainty were uniform across mothers, broad undifferentiated messaging might be enough. Instead, I find that uncertainty is concentrated in a meaningful subset of respondents and is most tightly related to behavior near the full schedule margin. That pattern supports a view in which targeted information and follow-up efforts are likely to be more useful than uniform campaigns, especially when they help mothers understand what completing the dose schedule changes and when appointments are due. At the same time, the muted booklet timing results caution against reading the paper as a demand-only story: uncertainty can coexist with follow-through barriers that communication alone cannot solve, a theme that is also prominent in recent evidence on malaria vaccine delivery, return visits, and schedule completion frictions in Ghana and the other pilot countries (Grant et al., 2022; Asante

et al., 2024; Jalang'o et al., 2025; Walldorf et al., 2025; Price et al., 2025; Isah et al., 2025).

This paper sits at the intersection of four literatures. The first studies how to elicit subjective expectations and how to use them in empirical work. Manski (2004) provides the foundational argument for eliciting probabilistic expectations directly rather than inferring them indirectly from choices. Subsequent work shows that probabilistic expectations can be collected credibly in rich survey environments and in developing country settings, and that they help discipline empirical models of education, fertility, and health behavior (Bound et al., 2001; Delavande and Rohwedder, 2008; Delavande, 2008; Delavande et al., 2011; Zafar, 2011; Arcidiacono et al., 2012; Giustinelli, 2016; Delavande and Kohler, 2016; Bachmann et al., 2023). My setting extends that tradition by treating lower and upper bounds not as incidental noise around a latent point belief, but as substantively meaningful objects that capture uncertainty about protection itself.

The second literature shows that respondents often hold and report imprecise probabilities and that those intervals are behaviorally informative rather than mere survey noise. Giustinelli et al. (2022) document this in expectations about late onset dementia, while Delavande et al. (2023) connect richer uncertainty attitudes to decisions under uncertainty. Recent health work shows that conditional risk beliefs, information, and imprecision predict later behavior (Giustinelli and Shapiro, 2024; Ciancio et al., 2024; Conti and Giustinelli, 2023; Delavande et al., 2025a; Kerwin and Pandey, 2026). I bring that measurement framework to a new vaccine context with multiple protection states and a concrete schedule completion margin. That application is useful not only because malaria vaccination is policy relevant in its own right, but also because it offers a setting where the distinction between planning and realized timing is unusually transparent.

The third literature concerns ambiguity and non subjective expected utility, abbreviated non SEU, decision rules. Knight (1921) and Ellsberg (1961) motivate the distinction between known risk and uncertainty about probabilities; Gilboa and Schmeidler (1989) and Walley (1991) provide canonical models of behavior under multiple priors and imprecise probabilities; Ghirardato et al. (2004) clarify the distinction between ambiguity and ambiguity attitude; Gilboa and Marinacci (2013) and Machina and Siniscalchi (2014) review the broader theoretical landscape; Bleichrodt et al. (2023) bring the Hurwicz representation closer to empirical testing; and rank dependent or probability weighting approaches provide nearby alternatives (Quiggin, 1982; Kahneman and Tversky, 1979; Tversky and Kahneman, 1992; Prelec, 1998). My empirical contribution is modest but disciplined: the transition specifications compare perceived changes in belief levels and perceived changes in interval width using the exact belief objects reported by mothers. The goal is not to claim sharp structural identification of a full demand model, but to evaluate which parts of the elicited belief interval line up with behavior in the field.

The fourth literature concerns immunization support, information design, and malaria vaccine rollout. Maternal support and learning interventions already show that immunization behavior depends not only on broad awareness, but also on how information is delivered, whether mothers engage actively with it, and how easily intentions can be converted into completed actions (Delavande et al., 2025b; Grabowska, 2025). On the malaria vaccine side, community perceptions predate formal rollout (Febir et al., 2013), the clinical evidence establishes meaningful but incomplete protection across dose states (RTS,S Clinical Trials

Partnership, 2015; Datoo et al., 2022), and the Ghana and multi-country implementation literature now spans early planning, uptake correlates, post introduction evaluation, routine program feasibility, and recent qualitative and systems evidence on return visit frictions (Grant et al., 2022; Yeboah et al., 2022; Adjei et al., 2023; Mumtaz et al., 2023; Nadeem and Bilal, 2023; Asante et al., 2024; Hussein et al., 2024; Jalang'o et al., 2025; Walldorf et al., 2025; Isah et al., 2025; Ekhator et al., 2025; Price et al., 2025; Welaga et al., 2026; UNICEF Ghana, 2024; World Health Organization, 2023). What those studies do not measure directly is whether mothers are uncertain about protection in a way that affects engagement even after conditioning on their best guess beliefs, and whether that uncertainty is more tightly linked to planning than to realized completion. That is the gap this paper addresses.

The rest of the paper proceeds as follows. Section 2 presents the decision framework and the empirical objects used in the transition analysis. Section 3 describes the setting, survey design, elicitation protocol, descriptive patterns, and empirical strategy. Section 4 reports the main results, beginning with scenario specific associations and then turning to transition based evidence, mechanism patterns, and decision rule comparison. Section 5 discusses the interpretation, limits, and policy implications of the findings. The appendix reports the full field materials, the descriptive summary table moved out of the main text, additional robustness checks, and dedicated sections on index construction and booklet data verification.

2 Decision Framework and Empirical Objects

This section introduces the decision environment, the elicited belief objects, and the empirical mapping used in the transition analysis. The framework is parsimonious by design, but it is still substantive: its purpose is to clarify which parts of the reported belief interval correspond to perceived protection gains and which correspond to changes in uncertainty, and therefore to discipline the interpretation of the regressions that follow.

2.1 Decision environment

Consider a mother deciding whether to move from a lower protection vaccination stage to a higher protection stage. Let $a \in \{0, 1\}$ denote the action, where $a = 1$ indicates completing the higher protection stage. Malaria infection is the bad event. Let U_H denote utility if the child remains healthy and U_S denote utility if malaria occurs, with $U_H > U_S$. The action has a net cost $C(a)$ that captures travel time, waiting time, and perceived disutility of vaccination. With a preference shock ϵ_a, expected utility under precise beliefs is

$$U(a) = -C(a) + p_a U_S + (1 - p_a)U_H + \epsilon_a, \tag{1}$$

where p_a is the perceived probability of malaria under action a.

2.2 Elicited belief objects

For each scenario s in {current, no doses, one dose, all doses}, respondents report a central belief p_{is}^C and, when not fully sure, a lower bound p_{is}^L and/or an upper bound p_{is}^H. The central belief is elicited first and is not constrained to equal the midpoint of the interval. If respondents report being sure (no higher and no lower), the implied range is zero. If only one bound is reported, the missing bound is not imputed.

The scenario level range (imprecision) uses a one-sided rule anchored at the central belief:

$$R_{is} = \begin{cases} p_{is}^H - p_{is}^L, & \text{if both bounds are available,} \\ p_{is}^H - p_{is}^C, & \text{if only the upper bound is available,} \\ p_{is}^C - p_{is}^L, & \text{if only the lower bound is available.} \end{cases} \tag{2}$$

This sequencing is close in spirit to recent health-expectations protocols that ask respondents to express uncertainty around a best guess (Delavande et al., 2025a; Kerwin and Pandey, 2026; Giustinelli et al., 2022), but the malaria module differs in two ways that matter for interpretation. Mothers could explicitly state that they were fully sure before any bounds were probed, and enumerators used laminated percent-chance visuals tailored to low-literacy field settings. Those design choices help explain why one-sided intervals and exactly zero ranges are both substantively meaningful in this survey. Ranges are missing when no bound is reported and the respondent is not explicitly sure. Missing bounds are treated as missingness, not inconsistency. A scenario is inconsistent only if a reported probability is outside the valid support, the central belief lies outside the reported bounds when both are provided, or the constructed range is negative or exceeds 100. Respondents with any inconsistent scenario are excluded from regressions. Appendix Table A1 summarizes the mapping from elicited objects to model notation and empirical variables. Appendix I shows that restricting attention to respondents who report both bounds materially attenuates the main engagement coefficient and removes statistical precision, so the headline results should be interpreted as applying to the baseline one-sided rule sample rather than as a bounds-invariant estimate.

The empirical analysis focuses on the α max-min proxy, which uses the lower bound and the range. When a bound is missing, the observation is retained for statistics that do not require that bound and dropped only from the relevant regression. This preserves sample size while keeping the mapping from elicited objects to model primitives transparent.

A measurement concern warrants explicit acknowledgment. Approximately 51.1% of respondents report only a single bound, so the one-sided range rule anchors the missing bound at the central belief p^C, which compresses R toward zero for a nonrandom subset of respondents. This systematic compression may conflate the psychological width of a mother's uncertainty with their willingness or ability to navigate the two-step elicitation format. The main specifications therefore complement the binary indicator $\mathbf{1}\{R_{is} > 0\}$ with continuous range specifications and a two-bound restriction. Those checks are materially weaker than the baseline indicator results, which suggests that the extensive margin of expressing any positive range is

more informative here than the exact width once a range is reported.

The α ratio has a direct behavioral interpretation in this setting. Because transitions map cleanly to the rollout decision margin, changes in the lower bound summarize perceived best-case protection gains, while changes in the range isolate shifts in uncertainty around the interval. Under the Hurwicz representation, the ratio of these coefficients identifies the ambiguity attitude weight that governs how respondents combine worst-case and best-case evaluations, following the identification logic in Delavande et al. (2025a). Throughout the transition analysis, a positive change denotes lower perceived infection risk or narrower uncertainty under the more protective stage. This identification relies on three conditions: linearity of utility in beliefs, no other ambiguity relevant objects in the error term, and orthogonality between the error and both Δp^L and ΔR. I use this proxy as a disciplined way to compare belief level responses and imprecision responses without imposing a full structural model.

2.3 Decision rules under imprecise beliefs

When beliefs are precise ($p_{is}^L = p_{is}^H = p_{is}^C$), the decision reduces to subjective expected utility. Under imprecise beliefs, I use decision rule representations that map the belief interval into a scalar object that can predict behavior.

Define the health loss utility gap as $\Delta U = U_H - U_S > 0$, so expected utility can be written as

$$U(a) = -C(a) + U_H - \Delta U \cdot p_a + \epsilon_a. \tag{3}$$

Because malaria infection is a bad event, the worst-case probability is the upper bound. The max-min rule therefore evaluates actions using p^H. A positive Δp^H means the worst-case infection probability falls under more doses, which should predict higher engagement. A minimax regret proxy evaluates actions at the midpoint of the bounds; in the transition setting I define the midpoint reduction as $\Delta p^M = 0.5(\Delta p^L + \Delta p^H)$, which is distinct from the central belief reduction Δp^C.

For the α max-min (Hurwicz) rule (Ghirardato et al., 2004), expected utility is a weighted average of best- and worst-case evaluations:

$$U(a) = -C(a) + \alpha \left[p_a^H U_S + (1 - p_a^H) U_H\right] + (1 - \alpha) \left[p_a^L U_S + (1 - p_a^L) U_H\right] + \epsilon_a, \tag{4}$$

which can be written as

$$U(a) = -C(a) + U_H + (U_S - U_H) \left[p_a^L + \alpha R_a\right] + \epsilon_a, \tag{5}$$

where R_a is the scenario level range. In differences across vaccination stages, the Hurwicz rule implies that behavior responds to the reduction in the lower bound Δp^L and to the reduction in imprecision ΔR, with the ratio of coefficients identifying α.

Proposition 1. *Under the α max-min representation with $\alpha \in (0, 1)$, the utility gain from moving to a more*

protective stage is increasing in Δp^L (the reduction in the lower bound infection probability; $\Delta p^L > 0$ means the best-case perceived risk falls, so the lower bound improves) and increasing in ΔR (the reduction in imprecision; $\Delta R > 0$ means the gap between upper and lower bounds narrows, compressing the worst-case). For a bad event like malaria infection, the worst-case probability is the upper bound p^H and the best-case is the lower bound p^L. Both changes increase utility. In the transition regression $Y_{it} = \gamma\,\Delta p^L_{it} + \eta\,\Delta R_{it} + \ldots$, the α max-min model predicts $\gamma > 0$ and $\eta > 0$; the SEU special case ($\alpha = 0$) predicts $\gamma > 0$ and $\eta = 0$; and the ratio η/γ identifies the ambiguity aversion weight α.

In the empirical analysis, I focus on this α max-min proxy because it uses the lower bound and the range, which can be constructed whenever at least one bound is reported. A structural note: since $R_a = p_a^H - p_a^L$, the objects Δp^L and ΔR are not independent: $\Delta R \equiv \Delta p^H - \Delta p^L$. The specification $\gamma\,\Delta p^L + \eta\,\Delta R$ is therefore equivalent to $(\gamma - \eta)\,\Delta p^L + \eta\,\Delta p^H$, from which the separate responses to best-case and worst-case reduction can be recovered by a linear transformation. The ratio η/γ identifies α only under the maintained assumption that utility is linear in the belief objects. Other decision rules are useful conceptual benchmarks, but they require additional objects (e.g., the upper bound) that are missing for a nontrivial share of respondents.

To quantify the implied α, I compute the ratio $\hat{\eta}/\hat{\gamma}$ from the transition regressions reported later in the paper together with a bootstrapped 95% confidence interval (500 repetitions, clustered at the facility level). Appendix Table A49 reports these estimates for all three transitions. Across the admissible bootstrap ratios, point estimates range between 0.55 and 0.78. I formally reject the SEU special case ($\alpha = 0$, equivalent to $\eta = 0$) at the 5% level for the one to all transition and at the 10% level for the no to all transition. These estimates should be interpreted as descriptive summaries of the implied weight rather than as structural parameters, given the linearization assumptions underlying the proxy.

Two clarifications about the transition regressions and the headline range are important. First, the [0.55, 0.78] range is derived from the bootstrapped ratio estimates in Appendix Table A49, specifically from the transitions where both $\hat{\gamma}$ and $\hat{\eta}$ are positive and the ratio falls in the theoretically admissible $(0, 1)$ interval. Second, raw panel level coefficient ratios in those regressions will sometimes fall outside $(0, 1)$ (including negative values or values exceeding one) due to estimation noise, imprecise identification in specific sub-panels, or transitions where either $\hat{\gamma}$ or $\hat{\eta}$ is small and imprecisely estimated. These out of bounds ratios do not represent structural α estimates; the bootstrapped confidence intervals in Appendix Table A49 are the appropriate object for inference on ambiguity aversion.

2.4 Empirical mapping and estimation

I focus on the three dose transitions that correspond to the rollout sequence: the transition from no doses to one dose, the transition from one dose to all doses, and the transition from no doses to all doses. Let s_0 denote the less protective scenario and s_1 the more protective scenario; this ordering is fixed by the vaccine schedule and is not reordered by reported beliefs.

For each transition t, I define:

$$\Delta p^L_{it} = p^L_{i,s_0} - p^L_{i,s_1}, \tag{6}$$

$$\Delta p^C_{it} = p^C_{i,s_0} - p^C_{i,s_1}, \tag{7}$$

$$\Delta p^H_{it} = p^H_{i,s_0} - p^H_{i,s_1}, \tag{8}$$

$$\Delta R_{it} = R_{i,s_0} - R_{i,s_1}, \tag{9}$$

$$\Delta p^M_{it} = 0.5(\Delta p^L_{it} + \Delta p^H_{it}). \tag{10}$$

The midpoint Δp^M is a function of bounds and is not the same as the central belief difference Δp^C. All variables are in percentage points.

The outcome is the intentional behavior index (all protective behavior). The main proxy regression links behavior to perceived reductions in minimum risk and in imprecision:

$$Y_{it} = \mu_h + \gamma\, \Delta p^L_{it} + \eta\, \Delta R_{it} + X_i'\delta + \varepsilon_{it}. \tag{11}$$

This specification corresponds to the α max-min (Hurwicz) representation in differences and provides a disciplined way to compare the role of perceived protection levels versus reductions in uncertainty. All regressions use ordinary least squares with facility fixed effects and cluster standard errors at the facility. Each transition is estimated on the nonmissing sample for the required belief objects.

2.5 Identification and interpretation

The regressions relate behavior to scenario specific belief objects conditional on controls and facility fixed effects. For the transition specifications, the regressors are within respondent differences across hypothetical scenarios, which reduces some purely level based heterogeneity in beliefs. The outcome remains cross sectional, however, and beliefs and intentions are still measured contemporaneously. I therefore interpret the coefficients as disciplined descriptive associations between elicited belief objects and behavior rather than as causal responses.

The main identification threat is selection into both range reporting and engagement. Mothers who report positive ranges may differ in motivation, information acquisition, record keeping, or health literacy in ways not captured by observed covariates. Facility fixed effects absorb local supply conditions, and Appendix I shows that adding enumerator fixed effects leaves the main engagement coefficient close to its baseline value. At the same time, Appendix Table A46 shows that adding engagement proxies can substantially attenuate the all doses imprecision coefficient, while knowledge proxies attenuate it less. Omitted variable bias therefore remains material. A definitive causal design would require exogenous shifts in imprecision or belief levels, such as a randomized information treatment.

3 Data, Elicitation, Measurement, and Empirical Strategy

3.1 Setting, sample, and survey implementation

The analysis uses survey data from 4,383 mothers in Ghana's Oti Region during the early phase of the R21/Matrix-M malaria vaccine rollout. Eligible respondents are women ages 15 to 49 who are permanent residents and are either pregnant or have a young child in the age range relevant for the malaria vaccination schedule. The study area has high malaria burden and was a natural place to study beliefs during the early phase of the malaria vaccine rollout, when familiarity with the protection profile and the dose schedule was still forming. In the rest of the paper, I use "malaria vaccine" as the general term when orienting the reader.

The mother sample comes from a door-to-door survey in the catchment areas of selected frontline vaccination facilities. The facility list was filtered in five steps. First, I kept only Community based Health Planning and Services (CHPS) compounds and health centers, which are the primary care facilities that regularly deliver Expanded Programme on Immunization services. Second, I required recent malaria vaccine activity during the preceding three months so that the sampled facilities were operating in a live rollout environment. Third, I retained only facilities running both fixed post and outreach vaccination services. Fourth, I required evidence that at least one new child had recently entered the schedule, as reflected in recent first dose delivery. Fifth, I excluded facilities with highly irregular weekly opening schedules. These restrictions were meant to keep the sample focused on functioning frontline sites where mothers faced comparable exposure to the vaccination program.[1]

The main survey was fielded from October 16, 2025 through November 24, 2025, a 39-day field period. Before that fieldwork began, the survey instrument itself was piloted for two weeks in two rural villages near Accra. That instrument pilot is distinct from the vaccine rollout and should not be confused with any pilot phase of the vaccination program. The pilot was used to test the question flow, the probability visuals, and the bounds elicitation sequence. Respondents in the pilot selected the two laminated probability formats at roughly similar rates, a pattern that later reappeared in the full sample, so both formats were retained in the final protocol. In addition, each enumerator completed out of sample practice interviews in the district of later assignment before the live survey started. These details matter because the paper's main variables depend on how respondents understood percent chances and interval questions.

Appendix Figures A5 and A6 document the training environment, piloting of the probability materials, and live survey implementation. Keeping the photographs in the appendix lets the paper retain the field context without interrupting the main empirical narrative.

The questionnaire combines a subjective belief module on malaria infection risk and vaccine protection with modules on preventive behaviors, vaccine intentions, appointment delays, trust, misinformation, and communications exposure. I exclude repeat observations to maintain a clean cross section. Throughout the

[1] A planning map of the sampled areas is archived in the project materials at `https://www.google.com/maps/d/u/0/viewer?mid=1PKAysxuCi9KMDXggvxMKgdMdJX-Nbss&ll=7.6918527954605045%2C0.16772500000000967&z=9`.

paper, the respondents are the mothers, and the elicited beliefs refer to the mother's assessment of malaria risk for her youngest child or incoming baby under alternative vaccination states.

The design therefore follows the structure of the real decision problem. It does not ask only whether a mother is generally favorable toward vaccination. It asks how she distinguishes between no doses, partial protection, and completion of the full schedule. That alignment between the elicitation scenarios and the dose sequence is what later allows the paper to move from descriptive scenario comparisons to transition based objects that can be interpreted as perceived protection gains and perceived reductions in uncertainty.

3.2 Behavioral outcomes and booklet based measures

The paper distinguishes carefully between two classes of outcomes. The first is *intentional behavior*: a preventive behavior index, a vaccination engagement index, and an overall protective behavior index. The vaccination engagement index is meant to capture active involvement with the vaccination process, planning to vaccinate, not delaying appointments, not missing appointments, and using the child's card or booklet to track the schedule. The preventive behavior index instead captures non vaccine malaria protection actions such as net use, repellents, and related preventive effort. Appendix Section C lists every component item and explains the index construction in detail.

The second class is realized follow-through measured from child health booklets. Enumerators transcribed malaria vaccination dates from the booklet, photographed each booklet page, and the data team audited transcriptions against the images. Those records support outcomes such as on-time dose receipt, the number of doses received on time, and the share of due doses completed within the recommended schedule window. I use the booklet outcomes as the most credible baseline source on realized vaccination history, but they are available only for the subset for whom booklet information is meaningful. This is not simply a generic missing data problem. Pregnant respondents and very young children may not yet have relevant malaria vaccine history recorded, and booklet based outcomes are only defined when the child's age and vaccination window make those measures meaningful. I therefore treat booklet analysis as an eligibility defined subsample rather than as a benchmark from which the rest of the sample attrited. Appendix D discusses booklet verification, administrative linkage limits at baseline, and why booklets remain the most trustworthy source for realized vaccination timing in this round of the study.

3.3 Belief elicitation and measurement

For each mother and scenario, the survey first elicits a best guess and then, if the respondent is not fully sure, lower and upper bounds. The four core scenarios are: the current situation, no malaria vaccine doses, one dose, and all doses. Visual training materials were central to the protocol. Enumerators presented two laminated visuals, an urn and balls display representing probability as "out of 100" and a 0 to 100 colored line with evenly spaced ticks, and then walked respondents through two practice questions on the chance of visiting a health facility in the next two weeks and the next two months. Only after that training and the

associated comprehension check did the malaria belief questions begin.

The wording of the main scenarios matters enough that the data section should show it, not only the appendix. The current situation question asks, in substance, for the percent chance that the respondent's youngest child or incoming baby will get malaria in the nearest rainy season if current routines continue. The no dose, one dose, and all doses questions repeat that structure while changing the vaccination state. For each scenario, the enumerator records the best guess, then asks whether the respondent is "really sure." If the respondent says yes, the implied range is zero. If not, the enumerator asks for the highest and lowest possible chances. That sequencing is important. The high share of zero ranges is not created by omitting the bounds question by mistake; it is part of the instrument design that allows respondents to state that they hold a point belief. Appendix A reports the exact wording, the screenshots, and the laminated visuals used in the field.

This scaffolding was intentional. Kerwin and Pandey (2026) provide the closest field comparator in an infectious disease setting, showing that respondents can report meaningful imprecise beliefs when the survey first anchors a best guess and then asks for uncertainty around it. My protocol adds in person laminated visuals, a short practice block, and an explicit "really sure" option because the malaria vaccine setting required mothers to distinguish no doses, partial protection, and full schedule completion in a numerically demanding environment. The broader design logic also aligns with Delavande et al. (2025b), who show in Pakistan that immunization behavior is highly sensitive to support and information frictions. Taken together, those papers motivate a protocol that first makes percent chances concrete and only then asks mothers to quantify protection under different vaccination states.

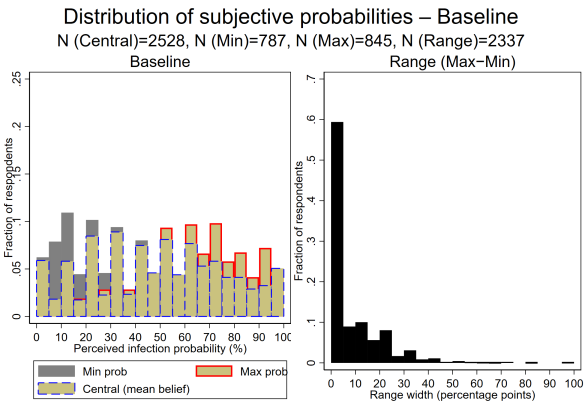
Heaping and focal answers are present but not dominant. Appendix Table A4 reports the share of central and bound responses at 0, 50, and 100 and at other multiples of ten. Central beliefs heap more than bounds, which is consistent with a best guess response being easier to round than an interval. Some heaping at focal values is common in subjective expectations surveys and is not specific to this instrument (Manski, 2004; Giustinelli, 2016; Delavande et al., 2023). The distributions nonetheless retain substantial mass away from focal points, supporting the use of continuous belief objects in the main analysis. I exclude respondents from all analysis if the malaria module was incomplete or if the percent chance comprehension check was missing or clearly failed. Within the remaining sample, a scenario is treated as inconsistent only if a reported probability lies outside $[0, 100]$, the central belief falls outside the respondent's own bounds when both are present, or the constructed range is negative or greater than 100. One-bound cases are retained except in specifications that require the missing bound.

The scenario level range for mother i in scenario s follows the one-sided rule introduced in Section 2: it is max minus min when both bounds are observed, max minus central when only the upper bound is observed, and central minus min when only the lower bound is observed. This rule preserves the fact that the best guess is elicited first and is not constrained to equal the midpoint of the interval. It also makes clear why the extensive margin of reporting any positive range may be informative even when exact width is measured imperfectly. Appendix B reports the practice order check, interval consistency diagnostics, and

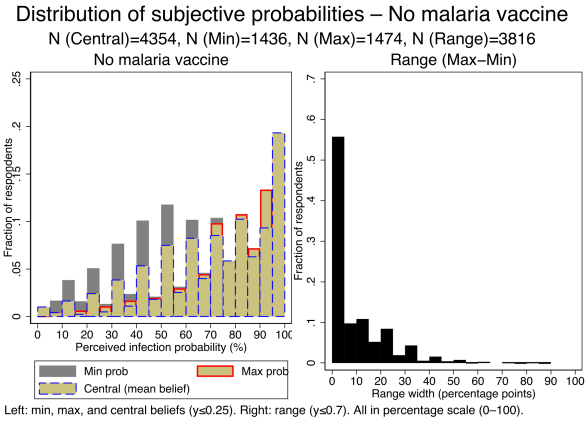
additional evidence on one bound reporting.

3.4 Descriptive evidence

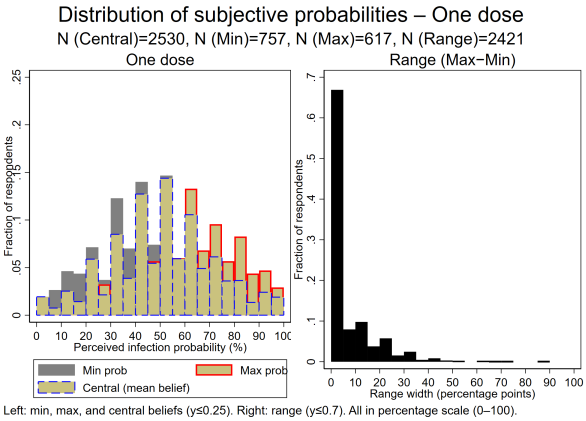
Appendix Tables A6, A7, and A8 report the full descriptive material for perceived infection risk, behavior items, and standardized indices. The main text highlights the same evidence through Figure 1, the two density panels in Figure 2, and the behavior and index panels in Figure 3.



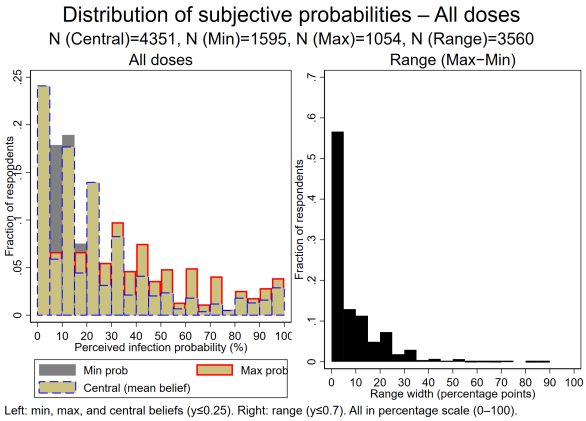
(a) Current scenario



(b) No doses scenario

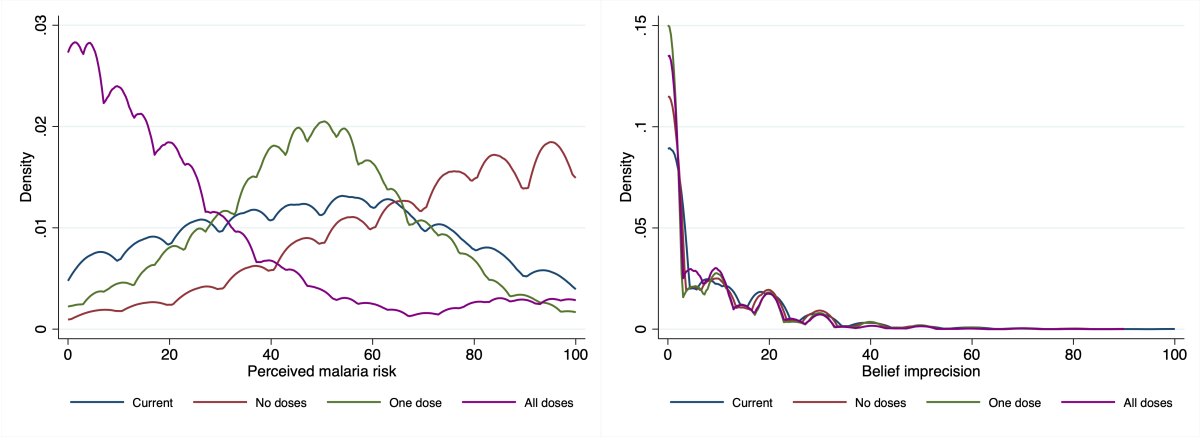


(c) One dose scenario



(d) All doses scenario

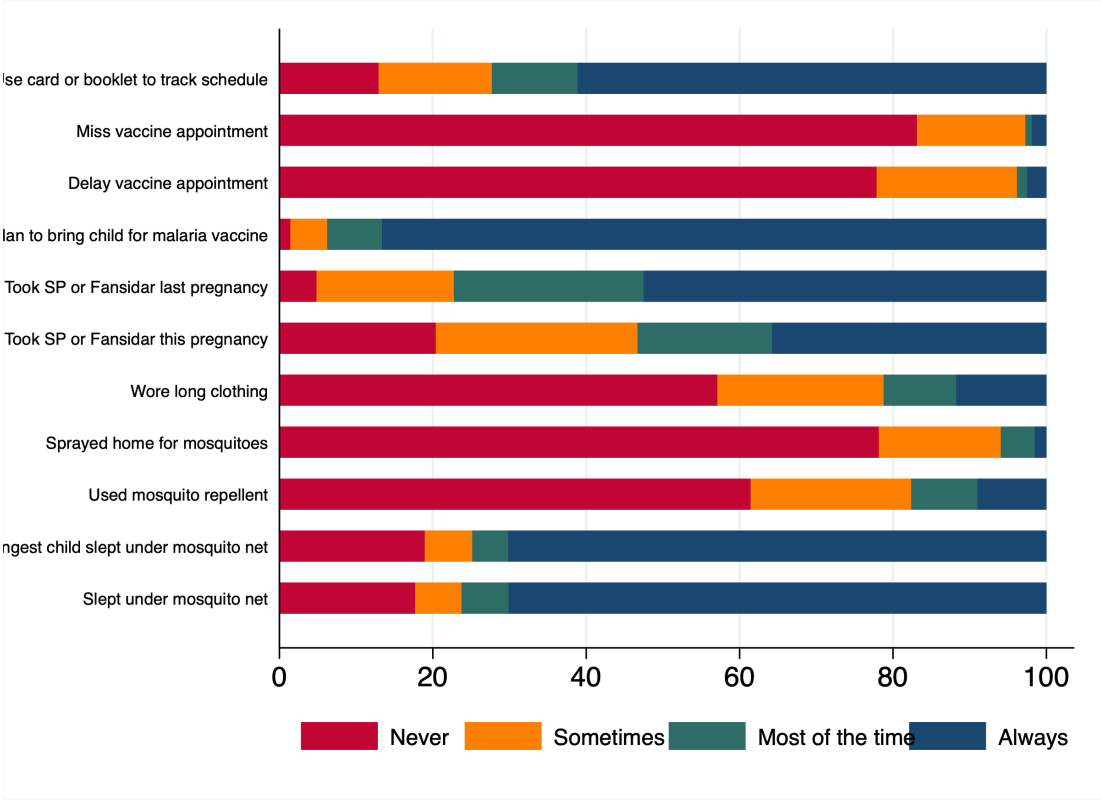
Figure 1: Distribution of central beliefs across vaccination scenarios



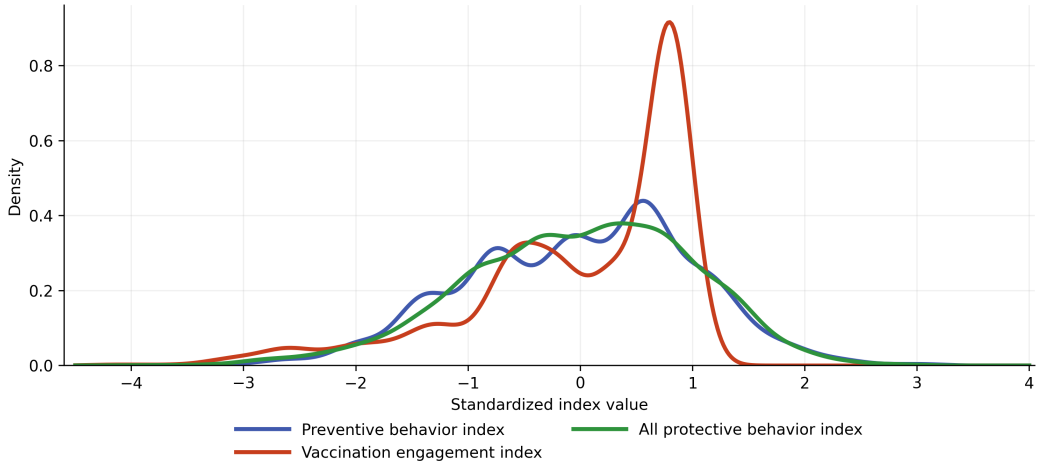
(a) Density of central beliefs

(b) Density of imprecision

Figure 2: Distribution of perceived infection risk and imprecision by vaccination scenario



(a) Behavior-item response distributions



(b) Density of standardized behavior indices

Figure 3: Behavior-item response distributions and standardized indices

Across these figures, three descriptive patterns stand out. First, Figure 1 shows that perceived infection risk is highest in the no dose scenario and lowest in the all doses scenario, with the current and one dose scenarios in between. Second, the left panel of Figure 2 shows that the central belief densities remain well separated across vaccination states, while the right panel shows that imprecision is concentrated near zero for many mothers but remains clearly positive for a meaningful subset. Third, Figure 3 shows the full behavior item and index distributions in the main text, so the descriptive evidence remains visible even though the full summary tables move to Appendix E. The appendix also reports additional descriptive figures on scenario level mean imprecision, the correlation structure of belief objects, how ranges vary with comprehension, and the overall distribution of belief ranges.

3.5 Empirical strategy

The main reduced form specifications relate scenario specific beliefs to behavioral outcomes of the form

$$Y_i = \mu_{h(i)} + \beta R_{is} + \gamma p_{is}^C + X_i'\delta + \varepsilon_i, \tag{12}$$

where Y_i is a behavioral outcome, R_{is} is the scenario specific belief range, p_{is}^C is the central belief for the same scenario, X_i is the standard control vector, and $\mu_{h(i)}$ denotes health facility fixed effects. I estimate all regressions with health facility fixed effects and cluster standard errors at the facility level. This is the natural level for both adjustments because mothers are sampled within facility catchment areas and share common supply conditions, outreach schedules, and local communication environments. The main text keeps the belief object and the behavioral margin aligned: current and no dose beliefs capture general perceived risk, while one dose and all doses beliefs are more directly tied to vaccination decisions.

The three intentional outcomes are standardized indices with mean zero and standard deviation one. The preventive behavior index aggregates seven malaria prevention items. The vaccination engagement index aggregates four items on planning, appointment adherence, and schedule tracking. The all protective behavior index combines all eleven components. I construct these indices using Anderson (2008) inverse covariance weights applied to standardized components, replacing missing component z scores with zero before weighting so that an index is defined when at least one component is observed. Because some items apply only to pregnant women, most notably the sulfadoxine pyrimethamine, or SP or Fansidar questions,[2] I discuss the unequal applicability issue explicitly in the paper and document it fully in Appendix C. I also report observed only and alternative construction robustness checks in Appendix I.

These estimates are descriptive associations rather than causal effects of beliefs on behavior. Even though the scenario objects are hypothetical and are therefore less mechanically tied to past actions than realized vaccination status, beliefs and intentions are still measured contemporaneously. The main value of the design is that it allows a disciplined comparison across scenarios and, later, across dose transitions.

[2]These components apply only to mothers who are currently pregnant or reporting on a recent pregnancy, so the estimation sample is mechanically smaller for those items. Appendix C documents the exact applicability rules.

Appendix I reports wild cluster bootstrap inference, heaping exclusions, two-bound restrictions, and false discovery rate adjusted q values for the family of scenario by outcome tests.

4 Results

All coefficients in this section are conditional associations rather than causal effects. The value of the results is that they compare, in a disciplined way, which parts of the elicited belief interval line up with different behavioral margins. Four patterns organize the evidence. First, the strongest scenario specific association appears in the all doses scenario and is specific to vaccination engagement rather than general prevention. Second, booklet-based timing outcomes are much weaker, which creates an important wedge between engagement and realized follow-through. Third, transition regressions indicate that perceived reductions in infection risk matter more than perceived reductions in uncertainty width. Fourth, the mechanism patterns are more consistent with active monitoring than with simple confusion, although they do not establish causal mediation.

4.1 Scenario specific imprecision and behavioral outcomes

Table 1 reports the main scenario specific associations. The current and no dose scenarios capture general perceived malaria risk, while the one dose and all doses scenarios more closely track beliefs about partial or complete vaccine protection. Panel A includes only the imprecision indicator, Panel B adds the scenario specific central belief, and Panel C decomposes the range into upside and downside components. Because the main outcomes are standardized indices, a coefficient of 0.10 corresponds to one tenth of a sample standard deviation in the relevant behavior margin.

Table 1: Scenario-specific imprecision and behavior outcomes

Scenario	Term	Preventive behavior	Vaccine engagement	All protective behavior
Panel A. Imprecision dummy only				
Current	Imprecision	-0.052 (0.044)	0.169*** (0.060)	0.015 (0.052)
Current	N	3843	3842	3843
No doses	Imprecision	-0.087 (0.053)	0.095 (0.064)	-0.035 (0.061)
No doses	N	3619	3617	3619
One dose	Imprecision	-0.027 (0.053)	0.170** (0.066)	0.044 (0.061)
One dose	N	3970	3968	3970
All doses	Imprecision	-0.003 (0.062)	0.218*** (0.071)	0.087 (0.072)
All doses	N	3359	3358	3359
Panel B. Imprecision + central belief				
Current	Imprecision	-0.055 (0.045)	0.163*** (0.061)	0.010 (0.054)
Current	Central	-0.001* (0.001)	-0.003*** (0.001)	-0.002*** (0.001)
Current	N	3843	3842	3843
No doses	Imprecision	-0.085 (0.053)	0.097 (0.065)	-0.033 (0.061)
No doses	Central	-0.001 (0.001)	-0.001 (0.001)	-0.001 (0.001)
No doses	N	3619	3617	3619
One dose	Imprecision	-0.028 (0.052)	0.171** (0.066)	0.043 (0.060)
One dose	Central	0.000 (0.001)	-0.001 (0.001)	0.000 (0.001)
One dose	N	3970	3968	3970
All doses	Imprecision	-0.005 (0.062)	0.216*** (0.071)	0.085 (0.072)
All doses	Central	-0.002** (0.001)	-0.004*** (0.001)	-0.003*** (0.001)
All doses	N	3359	3358	3359
Panel C. Upside and downside + central belief				
Current	Upside	-0.028 (0.050)	0.035 (0.051)	-0.017 (0.057)
Current	Downside	-0.046 (0.044)	0.079 (0.057)	-0.007 (0.048)
Current	Central	-0.001* (0.001)	-0.004*** (0.001)	-0.002*** (0.001)
Current	N	3843	3842	3843
No doses	Upside	0.020 (0.055)	0.071 (0.056)	0.053 (0.060)
No doses	Downside	-0.140*** (0.051)	-0.016 (0.056)	-0.131** (0.052)
No doses	Central	-0.001 (0.001)	-0.001 (0.001)	-0.001 (0.001)
No doses	N	3619	3617	3619
One dose	Upside	-0.093 (0.064)	-0.092 (0.056)	-0.118* (0.063)
One dose	Downside	0.012 (0.061)	0.190*** (0.056)	0.088 (0.065)
One dose	Central	0.000 (0.001)	-0.001 (0.001)	0.000 (0.001)
One dose	N	3970	3968	3970
All doses	Upside	-0.016 (0.053)	-0.068 (0.053)	-0.038 (0.054)
All doses	Downside	-0.009 (0.062)	0.208*** (0.067)	0.079 (0.072)
All doses	Central	-0.002** (0.001)	-0.004*** (0.001)	-0.004*** (0.001)
All doses	N	3359	3358	3359

Notes: Outcomes are standardized indices (mean 0, sd 1) constructed using Anderson (2008) inverse-covariance weights. The sample includes analysis-eligible respondents with nonmissing central belief and range for the scenario. Panel A reports coefficients on the scenario-specific imprecision dummy. Panel B adds the central belief for that scenario and reports both coefficients. Panel C adds upside and downside imprecision indicators and the central belief. Upside (downside) is set to zero when only the lower (upper) bound is missing so the sample is identical across panels for a given scenario and outcome; respondents can have both upside and downside equal to one. Inconsistent intervals are excluded. N is reported for each scenario and outcome. * p¡0.10, ** p¡0.05, *** p¡0.01.

The strongest association appears in the all doses engagement specification. In Panel A, the coefficient is 0.218, which implies about 0.22 standard deviations higher vaccination engagement for mothers who report any positive range. The corresponding all protective behavior coefficient is positive but less precise, while the central belief term is negative, consistent with more pessimistic beliefs about protection being associated with lower engagement. Supplementary continuous range specifications in Appendix F are much weaker, which suggests that the extensive margin of expressing any uncertainty carries more signal here than the exact reported width once uncertainty is present.

The directional decomposition in Panel C is also informative. Downside imprecision is more predictive than upside imprecision in the higher protection scenarios, especially for all doses engagement. That pattern does not line up cleanly with a pure worst-case interpretation, so I treat it as suggestive evidence that respondents may be reacting to best-case variation, reference points around the central belief, or survey based engagement processes that are not well summarized by a single extreme ambiguity rule. The comparison of decision rules later in the section helps discipline that interpretation but does not resolve it fully.

4.2 Booklet-based outcomes and the engagement follow-through wedge

I next relate scenario specific beliefs to booklet verified vaccination timing. These outcomes are less exposed to social desirability concerns than the self-reported engagement measures, but they are available only for the eligibility defined booklet subsample. Results for the youngest child appear in Appendix Table A19; the full outcome families appear in Appendix H.

The booklet coefficients are generally small and imprecise. Central beliefs are occasionally negative in the more protective scenarios, but imprecision itself shows little stable association with timing. I interpret that contrast as one of the most substantive results in the paper. Self reported engagement captures planning, attention, and willingness to keep track of the vaccine process, whereas booklet outcomes capture realized timing after all household and health system constraints have operated. The paper therefore distinguishes an engagement margin from a follow-through margin rather than treating them as mechanically identical. That distinction aligns with the broader immunization and malaria rollout literature, which shows that caregiver demand, reminder systems, clinic side delivery conditions, and return visit frictions jointly determine completion rather than reducing neatly to acceptance alone (Delavande et al., 2025b; Grant et al., 2022; Asante et al., 2024; Walldorf et al., 2025; Price et al., 2025; Isah et al., 2025).

Appendix Table A43 shows that this contrast is not primarily a sample composition result. When I restrict the survey outcomes to the mothers with observed booklet data, the all doses vaccine engagement coefficient remains close to its full sample value, 0.204 versus 0.218, and it remains statistically significant. By contrast, booklet timing and coverage outcomes on that same sample remain small and imprecise. Holding the sample fixed therefore sharpens the interpretation that imprecision is more closely linked to engagement and planning than to realized follow-through.

Several explanations are consistent with the wedge, and the paper should not oversell any one of them.

Mothers with wider ranges may seek more information, keep closer track of the schedule, and yet still face clinic constraints, household shocks, or transportation barriers that affect on-time completion. It is also possible that the information environment is good enough to prompt attention but not good enough to resolve uncertainty in a way that changes realized timing. Finally, because beliefs and engagement outcomes are elicited in the same survey, common method covariance may inflate the belief- engagement association relative to the relationship with independently observed booklet timing. For those reasons, I treat the booklet results as a conservative complement rather than a simple benchmark that overrides the engagement evidence.

4.3 Transition based evidence on perceived protection and imprecision

I next move from scenario specific associations to transition objects aligned with the dose sequence. The focus is the all protective behavior index, which is the pre specified intentional outcome that combines prevention and engagement.

Belief differences by behavior group. Table 2 compares central beliefs, minimum beliefs, maximum beliefs, and ranges for respondents below versus at or above the median of the all protective behavior index. The goal is not causal identification, but a first descriptive check of whether behaviorally more engaged mothers perceive larger protection gains across the dose transitions.

Table 2: Subjective infection probabilities by behavior group

Scenario	Measure	Below median	Above median	p-value
Panel A. No doses to one dose				
No doses	Central belief	69.1 (24.8) [2054]	70.5 (24.5) [2060]	0.062
	Maximum belief	68.6 (22.6) [1547]	70.0 (22.5) [1612]	0.084
	Minimum belief	60.0 (24.1) [1578]	62.5 (23.8) [1539]	0.004
	Range	8.9 (12.5) [1807]	7.0 (11.3) [1823]	0.000
One dose	Central belief	47.9 (21.9) [2055]	49.4 (20.5) [2056]	0.021
	Maximum belief	51.5 (21.6) [1664]	52.4 (20.3) [1668]	0.175
	Minimum belief	43.2 (20.2) [1814]	45.2 (19.5) [1843]	0.003
	Range	7.4 (11.5) [1977]	6.6 (11.3) [2004]	0.023
Panel B. One dose to all doses				
One dose	Central belief	47.9 (21.9) [2055]	49.4 (20.5) [2056]	0.021
	Maximum belief	51.5 (21.6) [1664]	52.4 (20.3) [1668]	0.175
	Minimum belief	43.2 (20.2) [1814]	45.2 (19.5) [1843]	0.003
	Range	7.4 (11.5) [1977]	6.6 (11.3) [2004]	0.023
All doses	Central belief	24.5 (26.4) [2051]	22.4 (24.7) [2058]	0.007
	Maximum belief	32.4 (26.4) [1308]	28.7 (24.9) [1277]	0.000
	Minimum belief	24.4 (23.9) [1543]	21.7 (22.0) [1535]	0.001
	Range	7.0 (10.6) [1682]	6.3 (9.8) [1688]	0.052
Panel C. No doses to all doses				
No doses	Central belief	69.1 (24.8) [2054]	70.5 (24.5) [2060]	0.062
	Maximum belief	68.6 (22.6) [1547]	70.0 (22.5) [1612]	0.084
	Minimum belief	60.0 (24.1) [1578]	62.5 (23.8) [1539]	0.004
	Range	8.9 (12.5) [1807]	7.0 (11.3) [1823]	0.000
All doses	Central belief	24.5 (26.4) [2051]	22.4 (24.7) [2058]	0.007
	Maximum belief	32.4 (26.4) [1308]	28.7 (24.9) [1277]	0.000
	Minimum belief	24.4 (23.9) [1543]	21.7 (22.0) [1535]	0.001
	Range	7.0 (10.6) [1682]	6.3 (9.8) [1688]	0.052

Notes: Behavior group split at the median of the all protective behavior index (Anderson 2008 weights). Cells report mean (SD) with N in brackets. Central beliefs are best-guess responses. Bounds equal the central belief when respondents report being sure; ranges use max–min when both bounds are available and the deviation from the central belief when only one bound is available. Scenarios flagged inconsistent are excluded. P-values test equality of below- versus above-median means for each row.

Behaviorally more engaged respondents report lower infection probabilities in the higher protection scenarios and higher infection probabilities in the less protected scenarios, which is consistent with perceiving larger protection gains. Range differences are smaller and less systematic. The descriptive split already points to a theme that continues in the regression results: belief levels appear to carry more of the action than range compression alone.

Perceived changes by demographic group. Table 3 summarizes perceived reductions in minimum infection risk and in imprecision for the three dose transitions by key demographic groups.

Table 3: Perceived change in infection risk and imprecision by group

Group	N	Min-risk reduction (pp)	Range reduction (pp)
Panel A. No doses to one dose			
Overall	2868	18.2 (23.4)	0.8 (10.9)
Education: No education	651	18.2 (21.7)	0.8 (12.5)
Education: Primary	625	17.5 (24.2)	0.8 (11.4)
Education: JHS	1099	19.0 (23.5)	0.5 (9.7)
Education: Secondary+	492	17.5 (24.1)	1.2 (10.1)
Ethnicity: Akan	140	19.5 (25.7)	0.6 (9.2)
Ethnicity: Ewe	822	19.0 (24.4)	0.2 (9.7)
Ethnicity: Guan	456	22.1 (23.6)	0.8 (8.9)
Ethnicity: Other	1449	16.4 (22.3)	1.1 (12.1)
Income: Below median	501	18.9 (24.5)	1.4 (10.4)
Income: At/above median	516	17.5 (21.9)	0.7 (9.7)
Panel B. One dose to all doses			
Overall	2843	21.9 (25.3)	0.8 (10.0)
Education: No education	636	21.7 (23.6)	1.2 (11.4)
Education: Primary	647	22.0 (25.1)	1.1 (10.4)
Education: JHS	1071	21.4 (26.6)	0.5 (9.0)
Education: Secondary+	488	23.0 (25.0)	0.6 (9.6)
Ethnicity: Akan	138	23.4 (22.6)	-0.2 (6.1)
Ethnicity: Ewe	849	20.9 (25.8)	0.4 (9.5)
Ethnicity: Guan	443	26.1 (24.4)	0.4 (8.3)
Ethnicity: Other	1411	21.1 (25.5)	1.2 (10.9)
Income: Below median	468	21.8 (25.1)	0.8 (9.8)
Income: At/above median	533	17.8 (26.6)	0.7 (7.9)
Panel C. No doses to all doses			
Overall	2411	38.3 (33.1)	1.3 (10.9)
Education: No education	546	38.4 (31.0)	2.0 (12.3)
Education: Primary	546	36.5 (33.2)	1.5 (11.0)
Education: JHS	910	38.3 (33.9)	0.8 (9.4)
Education: Secondary+	408	40.5 (33.7)	1.3 (11.6)
Ethnicity: Akan	117	44.2 (31.4)	0.1 (9.5)
Ethnicity: Ewe	693	36.4 (33.1)	0.4 (10.1)
Ethnicity: Guan	381	47.0 (30.7)	1.0 (9.5)
Ethnicity: Other	1219	36.1 (33.4)	2.0 (11.7)
Income: Below median	406	38.8 (33.8)	1.7 (11.0)
Income: At/above median	461	33.6 (34.8)	1.1 (9.2)

Notes: Each panel reports within-person changes between scenarios. Minimum beliefs use the reported lower bound; respondents who report being sure (no higher and no lower) have the minimum set equal to the central belief. Ranges use max–min when both bounds are available, otherwise max–central or central–min when only one bound is available; if respondents report being sure, the range is set to zero. Scenarios flagged inconsistent are excluded. Standard deviations in parentheses. Sample sizes vary by panel because each transition requires valid beliefs in both scenarios.

Across all transitions, perceived reductions in minimum risk are positive and material, whereas perceived reductions in range are smaller and often near zero. The group gradients are modest, which suggests that the belief patterns are not driven by a single narrow demographic subgroup.

Perceived reductions and behavior. Table 4 is the main transition table. It relates perceived reductions in minimum risk and perceived reductions in range width to preventive and engagement indices.

Table 4: Protective behaviors and perceived reductions

	Preventive behavior	Vaccine engagement	All protective behavior
Panel A. No doses to one dose			
10 pp reduction in minimum risk	-0.012 (0.011)	-0.009 (0.013)	-0.014 (0.011)
10 pp reduction in range	-0.048*** (0.016)	0.007 (0.019)	-0.040** (0.017)
Alpha (ratio of coefficients)	4.078	-0.866	2.887
95% CI for α	[-3.139, 11.296]	[-6.737, 5.004]	[-1.510, 7.285]
F-stat equality (preventive vs engagement): dP	0.036	0.036	–
p-value equality (preventive vs engagement): dP	0.849	0.849	–
F-stat equality (preventive vs engagement): dR	6.080	6.080	–
p-value equality (preventive vs engagement): dR	0.014	0.014	–
N	2856	2854	2856
R-squared	0.136	0.138	0.131
Panel B. One dose to all doses			
10 pp reduction in minimum risk	0.019* (0.010)	0.035*** (0.010)	0.031*** (0.010)
10 pp reduction in range	-0.002 (0.025)	-0.015 (0.022)	-0.008 (0.025)
Alpha (ratio of coefficients)	-0.090	-0.438	-0.256
95% CI for α	[-2.636, 2.456]	[-1.737, 0.862]	[-1.825, 1.313]
F-stat equality (preventive vs engagement): dP	1.407	1.407	–
p-value equality (preventive vs engagement): dP	0.236	0.236	–
F-stat equality (preventive vs engagement): dR	0.227	0.227	–
p-value equality (preventive vs engagement): dR	0.634	0.634	–
N	2832	2832	2832
R-squared	0.141	0.152	0.140
Panel C. No doses to all doses			
10 pp reduction in minimum risk	0.009 (0.009)	0.028*** (0.010)	0.020** (0.008)
10 pp reduction in range	-0.019 (0.019)	0.009 (0.024)	-0.013 (0.019)
Alpha (ratio of coefficients)	-2.047	0.313	-0.650
95% CI for α	[-7.940, 3.845]	[-1.313, 1.940]	[-2.669, 1.369]
F-stat equality (preventive vs engagement): dP	2.313	2.313	–
p-value equality (preventive vs engagement): dP	0.128	0.128	–
F-stat equality (preventive vs engagement): dR	0.807	0.807	–
p-value equality (preventive vs engagement): dR	0.369	0.369	–
N	2400	2400	2400
R-squared	0.145	0.167	0.147

Notes: Outcomes are standardized indices (mean 0, sd 1) constructed using Anderson (2008) inverse-covariance weights. Regressors are scaled to 10 percentage-point changes. dP uses the minimum risk difference between the low- and high-protection scenarios; dR uses the range difference. Alpha is the ratio of the dR and dP coefficients. Equality tests compare preventive vs engagement coefficients within each transition. Inconsistent intervals (invalid codes, central outside bounds, or range outside [0,100]) are excluded; one-bound-available cases are retained and only affect specifications requiring the missing bound. * p¡0.10, ** p¡0.05, *** p¡0.01.

The clearest pattern appears in transitions that end at all doses. There, perceived reductions in minimum infection risk are more predictive of vaccination engagement and of the all protective behavior index than are reductions in range width. Panel A does not show the same strength for general preventive behavior, which is consistent with the idea that the transition objects are most relevant when the behavioral margin is close to completing the vaccine schedule. Appendix Table A36 shows that this ordering is preserved across alternative constructions of the transition objects. That pattern also fits the broader subjective expectations literature: conditional protection gains often carry more direct behavioral content than reduced form uncertainty summaries alone, even when the latter remain informative about learning and information processing (Manski, 2004; Arcidiacono et al., 2012; Giustinelli and Shapiro, 2024; Delavande et al., 2025a; Conti and Giustinelli, 2023).

4.4 Correlates of imprecision and mechanism evidence

I use mechanism proxies to characterize what imprecision captures in this setting. Following the diagnostic approach in the imprecise beliefs literature (Delavande et al., 2025a; Kerwin and Pandey, 2026; Giustinelli et al., 2022), I group proxies into five buckets: (i) knowledge and understanding, (ii) engagement and planning, (iii) trust, hesitancy, and rumors, (iv) access constraints and frictions, and (v) salience and recent illness. For each proxy M, I report mean differences by imprecision status and estimate regressions of the form

$$M_i = \mu_{h(i)} + \beta\, \mathbf{1}\{R_{is} > 0\} + \theta\, p^C_{is} + X_i'\delta + \varepsilon_i, \tag{13}$$

which mirrors the main specification with facility fixed effects and controls. A positive $\hat{\beta}$ indicates that mothers with a positive belief range have higher values of mechanism proxy M_i, conditional on the central belief, controls, and facility fixed effects. Each column is estimated separately by scenario; I emphasize the all doses scenario because it is the most behaviorally relevant. These are descriptive associations rather than causal mediation. Appendix Table A46 reports two panels: Panel A summarizes imprecision coefficients in the mechanism regressions, and Panel B shows how the imprecision coefficient in the all protective behavior regression changes when each mechanism proxy is added as a control. The exact items, coding rules, and index constructions are listed in the mechanism variable documentation.

An important caveat applies to this section: because mechanism proxies such as schedule knowledge, planning intensity, and tracking behavior are elicited in the same survey as beliefs and outcomes, they may act as omitted variables that load simultaneously on belief objects (Δp^L, ΔR) and on engagement outcomes. Positive associations between imprecision and planning proxies could therefore partly reflect a shared latent trait, motivated health engagement, rather than a causal channel from imprecision to behavior. I treat the mechanism evidence as diagnostic and descriptive rather than as causal mediation, and the correlations should be read as characterizing what types of mothers hold wide ranges, not as establishing why wide ranges predict engagement.

The key conceptual contrast is between a *confusion* story and an *active monitoring* story. Under the

confusion interpretation, imprecision should be associated with lower knowledge, lower trust, and greater hesitancy or rumor exposure. Under the active monitoring interpretation, it should be associated with planning, communications exposure, and timing knowledge. A third channel, access constraints, may generate imprecision for engaged mothers who face unpredictable supply-side conditions. This active monitoring interpretation is also consistent with recent evidence that imprecision predicts updating to new disease risk information (Kerwin and Pandey, 2026), that agency in information provision can strengthen learning in Ghana (Grabowska, 2025), and that maternal support and reminder systems can improve immunization follow-through even when beliefs are not the only constraint (Delavande et al., 2025b).

Knowledge and understanding show the sharpest signal through vaccine timing knowledge. Knowledge of when malaria vaccination starts and knowledge of the malaria schedule are consistently positive across scenarios, with coefficients around 0.16 to 0.20 and the largest in the all doses scenario (0.199). By contrast, general malaria knowledge and self assessed knowledge of "when to vaccinate" are small and unstable, and knowledge of the first injectable age is negative in the no doses and one dose scenarios. This pattern suggests that imprecision is not simply low knowledge overall; it is concentrated in the specific malaria vaccine schedule domain, which is precisely where the beliefs question is anchored.

Engagement and planning proxies show the clearest positive signal. The engagement index is positive in every scenario (0.096 to 0.138), on-time intentions are positive from the no doses scenario onward and largest in the all doses scenario (0.054, 0.076, and 0.101), and health communications intensity is positive in the current, no doses, and one dose scenarios but smaller and less precise in the all doses scenario. Planning system indicators are positive in every scenario, while tracking intentions are especially large in the current scenario. These patterns are consistent with active monitoring: mothers who report wider ranges are more likely to plan, track, and be exposed to communications about vaccination.

Trust, hesitancy, and rumors point in the same direction. Trust in vaccine safety and in health workers is positively associated with imprecision in all scenarios (0.040 to 0.077). Hesitancy indicators are negative, especially outside the current situation scenario, and rumor exposure is weak or negative, particularly in the no doses scenario. This evidence does not support a story in which imprecision is primarily driven by misinformation or distrust.

Access constraints and frictions show mixed evidence. Reported difficulty in the last vaccination visit is positive from the no doses through all doses scenarios (0.063 to 0.092), and behavioral frictions (busy, forgot, inconvenient time) are positive mainly in the current and no doses scenarios (0.064 and 0.060). Structural frictions (distance, stockouts, closed facilities) and travel time are small or negative. This suggests that access constraints exist but do not dominate the imprecision pattern.

Salience, records, and recent illness are weaker but still informative. Recent illness and malaria salience are near zero, while prevention engagement is modestly positive (0.025 to 0.037). Record quality and booklet availability are consistently positive (0.014 to 0.020), indicating that imprecision is higher among mothers with better documentation and record keeping rather than among those disconnected from the system.

Overall, the correlates are more consistent with "active monitoring with some friction" than with confu-

sion alone. Wider belief ranges are associated with planning, timing knowledge, communications exposure, and trust, while hesitancy and rumor exposure are weakly related or negative. Access constraints matter at the margin but do not overturn the main pattern. This narrative coheres with the reduced form results: imprecision is most strongly linked to engagement outcomes rather than booklet timing, which is more likely to be constrained by supply-side factors. The pattern is also consistent with broader evidence that imprecision often reflects how people process and update information rather than simple lack of awareness (Delavande et al., 2025a; Kerwin and Pandey, 2026; Giustinelli et al., 2022). Recent malaria vaccine implementation work points to a similar combination of active demand and residual frictions: caregivers may understand the schedule and still miss or delay later doses because the operational environment remains complex (Asante et al., 2024; Walldorf et al., 2025; Price et al., 2025; Isah et al., 2025).

4.5 Decision rule comparison

I treat the model comparison evidence as *descriptive guidance* rather than formal model selection. Bayesian information criterion differences of one point or less are well below the conventional threshold of six points required for strong evidence against a model, so I do not claim to rank decision rules decisively from the data. Instead, I use the comparison to ask which belief objects are most informative for each transition, and I complement Akaike and Bayesian information criterion patterns with the implied α estimates from Section 2.

The analysis uses the one-sided range rule and excludes inconsistent intervals. Because each decision rule requires different belief objects, the estimating sample can differ by model; all tables report Ns. Appendix Table A47 summarizes the belief inputs used by each rule. Appendix Table A48 reports Akaike and Bayesian information criterion comparisons using a common intersection sample, so that fit differences are not driven by sample changes. Those comparisons do not consistently favor a single rule: max-min has the lowest Bayesian information criterion for the no doses to one dose transition, while SEU or the midpoint proxy is marginally best in the other two transitions, and all gaps are small. Appendix Table A49 separately reports admissible bootstrap ratios in the range $\hat{\alpha} \in [0.55, 0.78]$. Taken together, these results keep moderate ambiguity aversion in the set of plausible summaries, but they do not provide decisive model selection evidence against nearby alternatives.

The directional asymmetry is informative in its own right. Under max-min ($\alpha = 1$), only the upper bound matters; under SEU ($\alpha = 0$), neither bound beyond the central belief matters. The stronger role for downside imprecision fits neither benchmark cleanly. It is more consistent with SEU-adjacent or optimism-weighted rules that place extra weight on best-case evaluations. I therefore treat the moderate α estimates as descriptive summaries rather than as clean evidence of worst-case ambiguity aversion.

5 Discussion and Conclusion

This paper studies whether imprecise beliefs about malaria vaccine protection predict behavior during a new rollout, and whether the behavioral relevance of those intervals reflects the level of perceived protection, the width of the belief interval, or both. Using a survey of 4,383 mothers in Ghana, I elicit a central belief together with lower and upper bounds on malaria infection risk under four vaccine scenarios and link those belief objects to standardized indices of preventive behavior, vaccination engagement, and booklet verified timing. The main message is that belief imprecision is common, right skewed, and behaviorally informative, but its clearest relationship is with engagement rather than with realized timing. In that sense, the paper contributes simultaneously to the subjective expectations literature, the empirical literature on imprecise beliefs, the ambiguity literature, and the recent malaria vaccine rollout literature (Manski, 2004; Giustinelli et al., 2022; Delavande et al., 2025a; Kerwin and Pandey, 2026; Asante et al., 2024; Hussein et al., 2024; Welaga et al., 2026).

Three findings summarize the evidence. First, imprecision is prevalent but far from universal. More than half of respondents report a zero range in any given scenario, yet a substantial minority report positive intervals and the distribution of positive ranges has a long right tail. Mothers therefore do not appear either uniformly confused or uniformly certain. Instead, the data reveal a meaningful subset of respondents who can articulate a clear best guess while still admitting uncertainty about the amount of protection the vaccine provides. Second, that imprecision predicts engagement much more clearly than booklet based timing. In the all doses scenario, reporting any positive range is associated with roughly 0.22 standard deviations higher vaccination engagement, whereas the corresponding booklet coefficients are close to zero. Third, the transition specifications show that perceived reductions in infection risk are more predictive of engagement than reductions in interval width. The structural proxy summaries therefore support moderate ambiguity aversion as a useful descriptive summary, but the strongest conclusion is simpler: mothers respond primarily to how much safer they think the child becomes, while the uncertainty margin plays a secondary role.

That engagement and follow-through wedge is central for interpretation. One possibility is active monitoring: mothers who are uncertain seek more information, pay closer attention to schedule details, and therefore report stronger planning behavior, even if what they learn does not fully resolve their uncertainty. A second possibility is that the information environment generates attention without generating clarity, so engagement rises while uncertainty persists. A third possibility is that the demand-side response is real, but later clinic constraints, transport costs, competing household demands, migration, or appointment frictions prevent that engagement from translating into on-time completion. Because beliefs and self-reported engagement are measured in the same survey and the design is cross sectional, the paper cannot adjudicate fully among these channels. It can, however, show that the wedge is systematic and that it is difficult to explain using a pure "beliefs do not matter" account. That interpretation is also consistent with recent malaria vaccine and immunization evidence emphasizing that follow-through depends on the interaction between household demand, support systems, and delivery conditions rather than on willingness alone (Delavande

et al., 2025b; Grant et al., 2022; Asante et al., 2024; Walldorf et al., 2025; Price et al., 2025; Isah et al., 2025).

The magnitude of the engagement result is not trivial. A 0.22 standard deviation increase in the vaccination engagement index corresponds to a meaningful shift in planning, appointment keeping, and record use, not merely to a small statistical change in one isolated item. The belief level coefficients point in the same direction: more pessimistic beliefs about protection under the all doses scenario are associated with lower engagement, while larger perceived minimum risk reductions in the transition regressions are associated with higher engagement. Read together, the reduced form and transition evidence suggest that mothers respond to the expected benefit of completing the schedule, but they do so in an environment where their understanding of that benefit remains incomplete.

The mechanism results help narrow the interpretation further. Wider belief ranges are positively associated with vaccine schedule knowledge, planning intensity, health communications exposure, trust in health workers, and record keeping, while they are weakly negatively associated with hesitancy and rumor exposure. That pattern is hard to reconcile with a simple confusion story in which wide intervals merely reflect scale misunderstanding or low health literacy. At the same time, it does not imply that imprecision is desirable or that uncertainty is itself motivating behavior in a beneficial way. A more plausible reading is that imprecision is concentrated among mothers who are actively trying to navigate a new and complex vaccine environment. In this setting, wider ranges identify respondents who are engaged enough to recognize what they do not yet know.

Several additional pieces of evidence point in the same direction. The practice ordering checks and the moderate cross scenario correlation of ranges suggest that respondents are not reporting arbitrary intervals. The elicitation module used visual aids and two practice questions before the malaria scenarios, which helps distinguish genuine uncertainty from misunderstanding of the percent chance scale. Likewise, the booklet selection patterns indicate that mothers who can produce booklets are not simply the least uncertain respondents. They report somewhat higher central beliefs but broadly similar ranges, which cautions against treating the booklet subsample as a selected group of unusually precise mothers. These diagnostics do not eliminate every measurement concern, but they make it harder to dismiss the intervals as noise alone.

The booklet results still require caution. The eligibility defined booklet subsample is the correct sample for realized timing, but it is smaller and more selective than the full engagement sample. Some mothers in the survey had children too young for a meaningful malaria vaccine history, some were pregnant, and some were interviewed before the relevant vaccine history window could exist. Those are substantive eligibility limits, not generic missing data, and they are precisely why the booklet analysis should be read as evidence on realized follow-through among children for whom timing is already meaningful. Even within that sample, near zero booklet coefficients should not be read as definitive proof of no belief effect. If households without usable booklets are less engaged or face tighter access constraints, then the booklet estimates may understate the strength of the relationship between beliefs and realized timing.

The transition analysis also deserves a measured interpretation. The structural proxy regressions do not

show that range reductions are irrelevant; they show that, once perceived protection gains are accounted for, the extra explanatory power of range reductions is comparatively limited. The implied $\hat{\alpha}$ values in Appendix Table A49 fall between 0.55 and 0.78, which is consistent with moderate ambiguity aversion rather than either polar benchmark. But the model comparison evidence does not cleanly separate nearby decision rules, and the dominance of downside imprecision in some reduced form specifications does not line up neatly with the starkest worst-case reading of α max-min. For that reason, the decision rule comparison is best treated as disciplined descriptive guidance rather than as sharp structural selection. The paper's strongest behavioral claim does not require more than that.

External validity is plausible but not automatic. The empirical setting is a specific region during the early stage of a new malaria vaccine rollout, so the level of uncertainty documented here need not carry over mechanically to areas with longer vaccine experience, stronger supply chains, or different baseline malaria environments. Even so, the measurement protocol is portable. Eliciting a best guess together with lower and upper bounds using simple visual aids and practice questions can be implemented in other vaccine settings at relatively low-cost. The broader qualitative pattern documented here, right-skewed imprecision, a stronger link to planning than to realized timing, and a closer behavioral relationship with perceived protection gains than with range compression alone, is likely to be relevant whenever mothers are making multi-dose decisions under genuine uncertainty about a novel intervention.

The policy implications follow directly from that interpretation. First, measurement matters. Surveys that elicit only a best guess infection probability miss the width of the belief interval and therefore miss information that helps explain planning and follow-through behavior. Adding lower- and upper-bound follow-ups is a low-cost modification that yields richer program diagnostics and a more credible picture of the demand-side environment. Second, communication should focus on clarifying what additional doses change. The results are more consistent with uncertainty about protection and schedule completion than with generalized hesitancy. Messaging that explains the expected protection profile of partial and complete vaccination, and that clarifies when additional doses are due, is therefore more tightly aligned with the empirical patterns than generic awareness campaigns. Third, communication should be paired with delivery improvements. The weak booklet timing response is a reminder that mother beliefs operate inside a broader service delivery environment. Better information can improve engagement, but it cannot by itself eliminate stockouts, distance barriers, migration, or appointment frictions. That emphasis closely matches the recent rollout and qualitative evidence from Ghana and the other pilot countries, which highlights schedule clarity, return visit systems, and delivery constraints as joint determinants of completion (Grant et al., 2022; Jalang'o et al., 2025; Walldorf et al., 2025; Price et al., 2025; Isah et al., 2025).

The heterogeneity evidence points to the same practical lesson. The imprecision and engagement relationship is stronger among mothers of younger children, for whom the next vaccination decision is more immediate, and it is directionally stronger in settings where access frictions are likely to bind more tightly. These patterns reinforce the idea that information and follow-up interventions should be targeted rather than uniform. Mothers making an imminent completion decision are the group for whom uncertainty ap-

pears most behaviorally relevant, and they are also the group for whom schedule clarification and reminder systems are most likely to matter.

Three limitations bound the conclusions. First, the study is cross sectional, so it cannot track how imprecision evolves as mothers gain experience with the malaria vaccine schedule. Whether initially wide ranges narrow after later doses or after repeated contact with the health system remains an open question. Second, booklet outcomes are measured on the eligibility defined booklet subsample, which is the right sample analytically but still limits precision and the scope of inference for realized timing. Third, the summary indices depend on weighting and applicability decisions, including items that apply only to pregnant respondents or only to respondents with meaningful booklet histories. The appendix shows that the broad results are robust to reasonable alternatives, but the paper's contribution remains one of careful measurement and disciplined description rather than causal identification.

Within those limits, the contribution is still substantial. This paper shows that mothers do not enter a novel malaria vaccine rollout armed only with best guesses. Many hold genuine intervals over plausible protection outcomes, and those intervals contain behavioral information that point beliefs alone miss. The field evidence also clarifies where that information matters most: imprecision is most tightly linked to engagement with the vaccination process, whereas realized timing remains jointly shaped by beliefs and by the service environment. That distinction extends the empirical imprecise beliefs literature into a real vaccine rollout and extends the malaria vaccine literature beyond acceptance and uptake by measuring uncertainty over protection directly rather than inferring it from choices alone (Giustinelli et al., 2022; Delavande et al., 2025a; Kerwin and Pandey, 2026; Hussein et al., 2024; Welaga et al., 2026). It is useful both for empirical work on subjective expectations and for the practical design of vaccine demand diagnostics.

Future work can build on these findings in three directions. A longitudinal follow-up could re-elicit the same belief intervals later in the dose sequence to test whether ranges narrow as mothers accumulate experience and whether that narrowing predicts completion. A targeted information experiment could vary the protection information given to mothers in order to separate changes in the level of perceived protection from changes in uncertainty itself. And the same elicitation framework could be carried to other vaccine settings to assess whether the engagement and follow-through wedge is specific to malaria vaccination in Ghana or instead reflects a broader feature of how households respond to novel multi-dose technologies. Those are natural next steps. The main result of this paper is already clear: in a new malaria vaccine rollout, belief imprecision is not a residual nuisance around point expectations. It is a measurable and behaviorally relevant part of the informational environment that mothers face.

Appendix Overview

Appendix A presents the field materials, exact instrument pages, laminated visuals, and verbatim wording for the malaria belief module. Appendix B reports measurement diagnostics and data quality checks. Appendix C documents outcome construction, item applicability, weighting logic, and the handling of missing components. Appendix D explains booklet verification, sample eligibility, and the baseline limits of administrative linkage. Appendix E provides the full descriptive summary table moved out of the main text together with additional descriptive figures and tables. Appendix F reports continuous range specifications for intentional behavior. Appendices G and H collect the booklet-based outcomes. Appendix I reports robustness checks, including alternative specifications for perceived reductions, two-bound sample restrictions, wild cluster bootstrap inference, enumerator fixed effects, heaping exclusions, observed only indices, heterogeneity analysis, and false discovery rate adjusted q values. Appendix J reports the mechanism evidence. Appendix K documents decision rule mappings and model comparison tables.

A Field Materials and Exact Instrument Pages

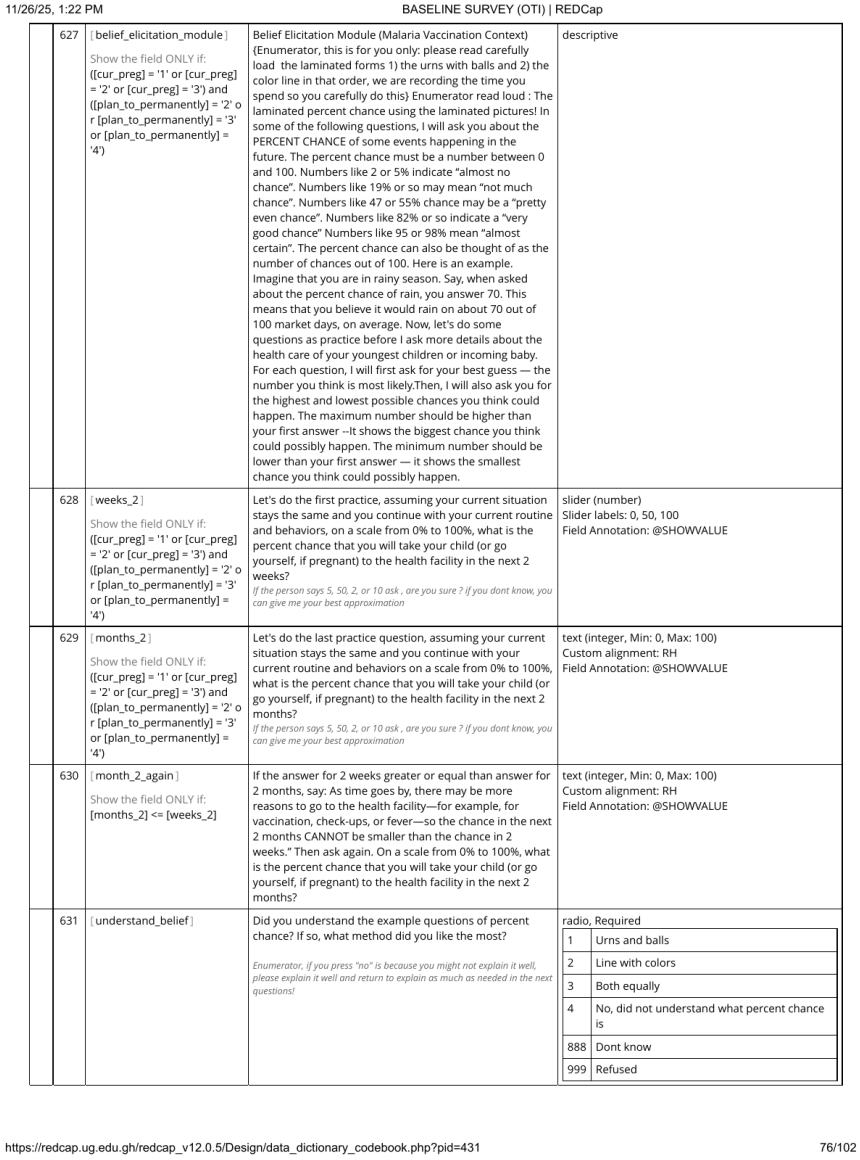
The module begins with the REDCap training page, two laminated visuals, two practice questions, a comprehension check, and then the malaria belief questions. The figures below show these materials in the order respondents encountered them in the field.

The same field material package was piloted for two weeks in two rural villages near Accra before the main survey launched. The pilot was used to verify that respondents understood the two probability formats, that the sequence from practice questions to malaria scenarios was workable in the field, and that the enumerators could administer the bounds protocol consistently. Both laminated formats were selected at roughly similar rates in the pilot and later in the main survey, which is why both were retained in the final protocol.

Laminated instruction sheet used with the visuals

The full laminated instruction sheet is reproduced below exactly as it was used with the probability visuals.

> **Understanding Percent Chance**
>
> *Please look at these two pictures*
>
> They help explain what we mean by percent chance, how likely it is that something will happen. We always talk about numbers between 0 and 100.
>
> **1. The First Picture: Urns with Balls**
>
> Each box, or urn, shows a different percent chance, from 0% to 100%. Each urn has 20 balls, some are red, and some are white. The red balls show the chance that something will happen. The more balls in red there are, the higher the chance of the event happening.



11/26/25, 1:22 PM BASELINE SURVEY (OTI) | REDCap

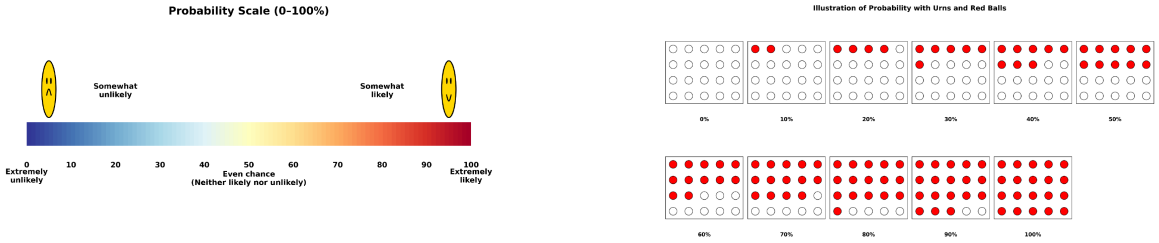
	627	[belief_elicitation_module] Show the field ONLY if: ([cur_preg] = '1' or [cur_preg] = '2' or [cur_preg] = '3') and ([plan_to_permanently] = '2' or [plan_to_permanently] = '3' or [plan_to_permanently] = '4')	Belief Elicitation Module (Malaria Vaccination Context) (Enumerator, this is for you only: please read carefully load the laminated forms 1) the urns with balls and 2) the color line in that order, we are recording the time you spend so you carefully do this) Enumerator read loud : The laminated percent chance using the laminated pictures! In some of the following questions, I will ask you about the PERCENT CHANCE of some events happening in the future. The percent chance must be a number between 0 and 100. Numbers like 2 or 5% indicate "almost no chance". Numbers like 19% or so may mean "not much chance". Numbers like 47 or 55% chance may be a "pretty even chance". Numbers like 82% or so indicate a "very good chance" Numbers like 95 or 98% mean "almost certain". The percent chance can also be thought of as the number of chances out of 100. Here is an example. Imagine that you are in rainy season. Say, when asked about the percent chance of rain, you answer 70. This means that you believe it would rain on about 70 out of 100 market days, on average. Now, let's do some questions as practice before I ask more details about the health care of your youngest children or incoming baby. For each question, I will first ask for your best guess — the number you think is most likely.Then, I will also ask you for the highest and lowest possible chances you think could happen. The maximum number should be higher than your first answer --It shows the biggest chance you think could possibly happen. The minimum number should be lower than your first answer — it shows the smallest chance you think could possibly happen.	descriptive
	628	[weeks_2] Show the field ONLY if: ([cur_preg] = '1' or [cur_preg] = '2' or [cur_preg] = '3') and ([plan_to_permanently] = '2' or [plan_to_permanently] = '3' or [plan_to_permanently] = '4')	Let's do the first practice, assuming your current situation stays the same and you continue with your current routine and behaviors, on a scale from 0% to 100%, what is the percent chance that you will take your child (or go yourself, if pregnant) to the health facility in the next 2 weeks? *If the person says 5, 50, 2, or 10 ask , are you sure ? if you dont know, you can give me your best approximation*	slider (number) Slider labels: 0, 50, 100 Field Annotation: @SHOWVALUE
	629	[months_2] Show the field ONLY if: ([cur_preg] = '1' or [cur_preg] = '2' or [cur_preg] = '3') and ([plan_to_permanently] = '2' or [plan_to_permanently] = '3' or [plan_to_permanently] = '4')	Let's do the last practice question, assuming your current situation stays the same and you continue with your current routine and behaviors on a scale from 0% to 100%, what is the percent chance that you will take your child (or go yourself, if pregnant) to the health facility in the next 2 months? *If the person says 5, 50, 2, or 10 ask , are you sure ? if you dont know, you can give me your best approximation*	text (integer, Min: 0, Max: 100) Custom alignment: RH Field Annotation: @SHOWVALUE
	630	[month_2_again] Show the field ONLY if: [months_2] <= [weeks_2]	If the answer for 2 weeks greater or equal than answer for 2 months, say: As time goes by, there may be more reasons to go to the health facility—for example, for vaccination, check-ups, or fever—so the chance in the next 2 months CANNOT be smaller than the chance in 2 weeks." Then ask again. On a scale from 0% to 100%, what is the percent chance that you will take your child (or go yourself, if pregnant) to the health facility in the next 2 months?	text (integer, Min: 0, Max: 100) Custom alignment: RH Field Annotation: @SHOWVALUE
	631	[understand_belief]	Did you understand the example questions of percent chance? If so, what method did you like the most? *Enumerator, if you press "no" is because you might not explain it well, please explain it well and return to explain as much as needed in the next questions!*	radio, Required 1 Urns and balls 2 Line with colors 3 Both equally 4 No, did not understand what percent chance is 888 Dont know 999 Refused

https://redcap.ug.edu.gh/redcap_v12.0.5/Design/data_dictionary_codebook.php?pid=431 76/102

Figure A1: Training page used before the malaria belief module

Examples:

- 0% (no chance): 0 balls in red out of 20. All the balls are white. The event has no chance of happening.
- 10% (very small chance): 2 balls in red out of 20. The event has a very small chance of happening.
- 20% (small chance): 4 balls in red out of 20. The event has a small chance of happening.
- 50% (even chance): 10 balls in red out of 20. The event has an even chance of happening.
- 80% (good chance): 16 balls in red out of 20. The event has a good chance of happening.
- 90% (very good chance): 18 balls in red out of 20. The event has a very good chance of



(a) Probability line visual

(b) Urns and balls visual

Figure A2: Laminated visuals used to explain percent chances

happening.

- 100% (certain): 20 balls in red out of 20. The event is certain to happen.

Remember: As the percent number goes up, the number of balls in red increases, from none at 0% to all 20 balls in red at 100%. You can say any number between 0 and 100, for example, 2, 5, 19, 47, 55, 82, 95, or 98, to describe how likely you think something is. The urns are only there to help you imagine what different chances look like.

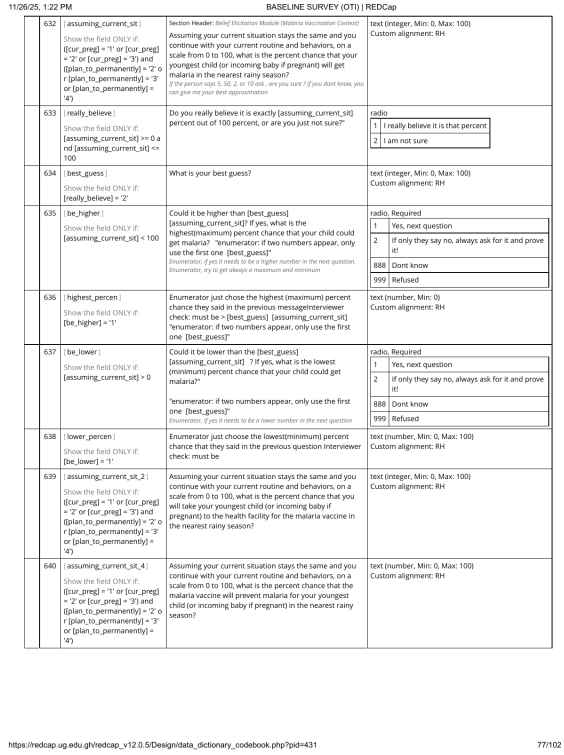
2. The Second Picture: The Color Line

The second picture uses colors to show the same idea, how likely something is to happen. The line goes from dark blue on the left (no chance) to dark red on the right (certain to happen). As the color changes from blue to red, the chance becomes higher. Every number between 0 and 100 fits somewhere on this line.

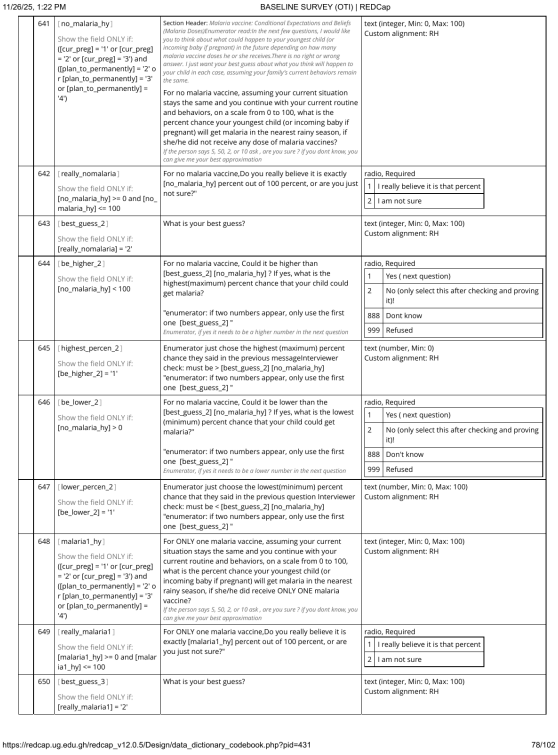
Examples:

- Dark blue: Numbers like 2 or 5 mean almost no chance.
- Light blue: Numbers like 19 mean not much chance.
- Yellow: Numbers like 47 or 55 mean an even chance. The event is just as likely to happen as not.
- Orange: Numbers like 82 mean a very good chance.
- Dark red: Numbers like 95 or 98 mean almost certain.

Remember: As the color moves from dark blue to dark red, the chance increases, from very unlikely to almost certain. You can use any number between 0 and 100 to describe how likely you think something is. The colors just help you see and explain the difference between low, middle, and high chances.



(a) Current situation, certainty, and bound follow-ups



(b) No vaccine and one dose scenarios

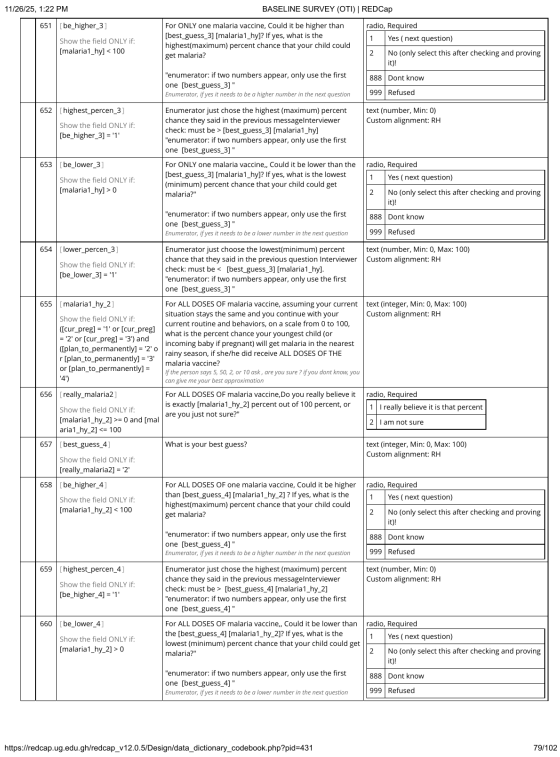
Figure A3: Exact instrument pages for the first malaria belief questions

Notes: The panels show field preparation and survey implementation for the malaria belief module. The training and piloting images document the probability materials used before live interviewing, and the survey images show the door-to-door data-collection environment. All photographed participants provided informed consent for research documentation and reproduction of these images in the paper.

Verbatim wording and follow-up logic

The materials above are shown in elicitation order. Enumerators first explained percent chances, walked through the practice questions, and then asked the malaria scenarios from current situation to no doses, one dose, and all doses, followed by the additional belief questions on vaccine take-up and protection. For each malaria scenario, enumerators first recorded a best guess and then asked whether the respondent was "really sure." If the respondent was not sure, enumerators asked for the highest and lowest possible chances.

Percent chance script (verbatim): "In some of the following questions, I will ask you about the percent chance of some events happening in the future. The percent chance must be a number between 0 and 100. Numbers like 2 or 5 percent indicate almost no chance. Numbers like 19 percent may mean not much chance. Numbers like 47 or 55 percent may be a pretty even chance. Numbers like 82 percent indicate a very good chance. Numbers like 95 or 98 percent mean almost certain. The percent chance can also be thought of as the number of chances out of 100. Here is an example. Imagine that you are in rainy season. Say, when asked about the percent chance of rain, you answer 70. This means that you believe it would rain on about 70 out of 100 market days, on average."

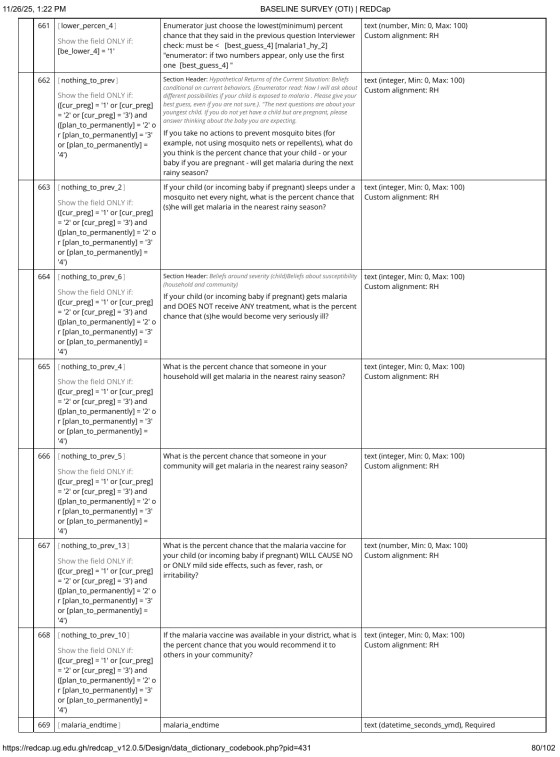


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651	[be_higher_3] Show the field ONLY if: [malaria1_hy] < 100	For ONLY one malaria vaccine, Could it be higher than [best_guess_3] [malaria1_hy]? If yes, what is the highest(maximum) percent chance that your child could get malaria? "enumerator: if two numbers appear, only use the first one [best_guess_3] " *Enumerator, if yes it needs to be a higher number in the next question*	radio, Required 1 Yes (next question) 2 No (only select this after checking and proving it)! 888 Dont know 999 Refused
652	[highest_percen_3] Show the field ONLY if: [be_higher_3] = '1'	Enumerator just chose the highest (maximum) percent chance they said in the previous messageInterviewer check: must be > [best_guess_3] [malaria1_hy] "enumerator: if two numbers appear, only use the first one [best_guess_3] "	text (number, Min: 0) Custom alignment: RH
653	[be_lower_3] Show the field ONLY if: [malaria1_hy] > 0	For ONLY one malaria vaccine,. Could it be lower than the [best_guess_3] [malaria1_hy]? If yes, what is the lowest (minimum) percent chance that your child could get malaria?" "enumerator: if two numbers appear, only use the first one [best_guess_3] " *Enumerator, if yes it needs to be a lower number in the next question*	radio, Required 1 Yes (next question) 2 No (only select this after checking and proving it)! 888 Dont know 999 Refused
654	[lower_percen_3] Show the field ONLY if: [be_lower_3] = '1'	Enumerator just choose the lowest(minimum) percent chance that they said in the previous question Interviewer check: must be < [best_guess_3] [malaria1_hy]. "enumerator: if two numbers appear, only use the first one [best_guess_3] "	text (number, Min: 0, Max: 100) Custom alignment: RH
655	[malaria1_hy_2] Show the field ONLY if: ([cur_preg] = '1' or [cur_preg] = '2' or [cur_preg] = '3') and ([plan_to_permanently] = '2' or [plan_to_permanently] = '3' or [plan_to_permanently] = '4')	For ALL DOSES OF malaria vaccine, assuming your current situation stays the same and you continue with your current routine and behaviors, on a scale from 0 to 100, what is the percent chance your youngest child (or incoming baby if pregnant) will get malaria in the nearest rainy season, if she/he did receive ALL DOSES OF THE malaria vaccine? *If the person says 5, 50, 2, or 10 ask , are you sure ? if you dont know, you can give me your best approximation*	text (integer, Min: 0, Max: 100) Custom alignment: RH
656	[really_malaria2] Show the field ONLY if: [malaria1_hy_2] >= 0 and [malaria1_hy_2] <= 100	For ALL DOSES OF malaria vaccine,Do you really believe it is exactly [malaria1_hy_2] percent out of 100 percent, or are you just not sure?"	radio, Required 1 I really believe it is that percent 2 I am not sure
657	[best_guess_4] Show the field ONLY if: [really_malaria2] = '2'	What is your best guess?	text (integer, Min: 0, Max: 100) Custom alignment: RH
658	[be_higher_4] Show the field ONLY if: [malaria1_hy_2] < 100	For ALL DOSES OF one malaria vaccine, Could it be higher than [best_guess_4] [malaria1_hy_2] ? If yes, what is the highest(maximum) percent chance that your child could get malaria? "enumerator: if two numbers appear, only use the first one [best_guess_4] " *Enumerator, if yes it needs to be a higher number in the next question*	radio, Required 1 Yes (next question) 2 No (only select this after checking and proving it)! 888 Dont know 999 Refused
659	[highest_percen_4] Show the field ONLY if: [be_higher_4] = '1'	Enumerator just chose the highest (maximum) percent chance they said in the previous messageInterviewer check: must be > [best_guess_4] [malaria1_hy_2] "enumerator: if two numbers appear, only use the first one [best_guess_4] "	text (number, Min: 0) Custom alignment: RH
660	[be_lower_4] Show the field ONLY if: [malaria1_hy_2] > 0	For ALL DOSES OF malaria vaccine,. Could it be lower than the [best_guess_4] [malaria1_hy_2]? If yes, what is the lowest (minimum) percent chance that your child could get malaria?" "enumerator: if two numbers appear, only use the first one [best_guess_4] " *Enumerator, if yes it needs to be a lower number in the next question*	radio, Required 1 Yes (next question) 2 No (only select this after checking and proving it)! 888 Dont know 999 Refused

https://redcap.ug.edu.gh/redcap_v12.0.5/Design/data_dictionary_codebook.php?pid=431 79/102

(a) Full schedule scenario



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661	[lower_percen_4] Show the field ONLY if: [be_lower_4] = '1'	Enumerator just choose the lowest(minimum) percent chance that they said in the previous question Interviewer check: must be < [best_guess_4] [malaria1_hy_2] "enumerator: if two numbers appear, only use the first one [best_guess_4] "	text (number, Min: 0, Max: 100) Custom alignment: RH
662	[nothing_to_prev] Show the field ONLY if: ([cur_preg] = '1' or [cur_preg] = '2' or [cur_preg] = '3') and ([plan_to_permanently] = '2' or [plan_to_permanently] = '3' or [plan_to_permanently] = '4')	Section Header: *Hypothetical Returns of the Current Situation: Beliefs conditional on current behaviors. (Enumerator read: Now I will ask about different possibilities if your child is exposed to malaria . Please give your best guess, even if you are not sure.). "The next questions are about your youngest child. If you do not yet have a child but are pregnant, please answer thinking about the baby you are expecting.* If you take no actions to prevent mosquito bites (for example, not using mosquito nets or repellents), what do you think is the percent chance that your child - or your baby if you are pregnant - will get malaria during the next rainy season?	text (integer, Min: 0, Max: 100) Custom alignment: RH
663	[nothing_to_prev_2] Show the field ONLY if: ([cur_preg] = '1' or [cur_preg] = '2' or [cur_preg] = '3') and ([plan_to_permanently] = '2' or [plan_to_permanently] = '3' or [plan_to_permanently] = '4')	If your child (or incoming baby if pregnant) sleeps under a mosquito net every night, what is the percent chance that (s)he will get malaria in the nearest rainy season?	text (integer, Min: 0, Max: 100) Custom alignment: RH
664	[nothing_to_prev_6] Show the field ONLY if: ([cur_preg] = '1' or [cur_preg] = '2' or [cur_preg] = '3') and ([plan_to_permanently] = '2' or [plan_to_permanently] = '3' or [plan_to_permanently] = '4')	Section Header: *Beliefs around severity (child)Beliefs about susceptibility (household and community)* If your child (or incoming baby if pregnant) gets malaria and DOES NOT receive ANY treatment, what is the percent chance that (s)he would become very seriously ill?	text (integer, Min: 0, Max: 100) Custom alignment: RH
665	[nothing_to_prev_4] Show the field ONLY if: ([cur_preg] = '1' or [cur_preg] = '2' or [cur_preg] = '3') and ([plan_to_permanently] = '2' or [plan_to_permanently] = '3' or [plan_to_permanently] = '4')	What is the percent chance that someone in your household will get malaria in the nearest rainy season?	text (integer, Min: 0, Max: 100) Custom alignment: RH
666	[nothing_to_prev_5] Show the field ONLY if: ([cur_preg] = '1' or [cur_preg] = '2' or [cur_preg] = '3') and ([plan_to_permanently] = '2' or [plan_to_permanently] = '3' or [plan_to_permanently] = '4')	What is the percent chance that someone in your community will get malaria in the nearest rainy season?	text (integer, Min: 0, Max: 100) Custom alignment: RH
667	[nothing_to_prev_13] Show the field ONLY if: ([cur_preg] = '1' or [cur_preg] = '2' or [cur_preg] = '3') and ([plan_to_permanently] = '2' or [plan_to_permanently] = '3' or [plan_to_permanently] = '4')	What is the percent chance that the malaria vaccine for your child (or incoming baby if pregnant) WILL CAUSE NO or ONLY mild side effects, such as fever, rash, or irritability?	text (number, Min: 0, Max: 100) Custom alignment: RH
668	[nothing_to_prev_10] Show the field ONLY if: ([cur_preg] = '1' or [cur_preg] = '2' or [cur_preg] = '3') and ([plan_to_permanently] = '2' or [plan_to_permanently] = '3' or [plan_to_permanently] = '4')	If the malaria vaccine was available in your district, what is the percent chance that you would recommend it to others in your community?	text (integer, Min: 0, Max: 100) Custom alignment: RH
669	[malaria_endtime]	malaria_endtime	text (datetime_seconds_ymd), Required

https://redcap.ug.edu.gh/redcap_v12.0.5/Design/data_dictionary_codebook.php?pid=431 80/102

(b) Additional questions on vaccine take-up and protection

Figure A4: Exact instrument pages for the later malaria belief questions



(a) Probability-material demonstration during field preparation



(b) Enumerator training session for the belief module

Figure A5: Enumerator training and piloting of the belief module



(a) Door-to-door survey implementation with tablet entry



(b) Full classroom training session before deployment

Figure A6: Survey data collection environment

Visual aids (laminated examples): Enumerators used two laminated visuals to explain percent chances: (i) an urn and balls graphic with 100 balls of two colors to represent probability as "out of 100," and (ii) a 0 to 100 color line with evenly spaced tick marks. Enumerators presented both visuals, walked through the percent chance script, and then asked the respondent which visual they understood best. The chosen visual was used for all subsequent belief questions.

Practice question 1 (two weeks): "Assuming your current situation stays the same and you continue with your current routine and behaviors, on a scale from 0 to 100 percent, what is the percent chance that you will take your child (or go yourself, if pregnant) to the health facility in the next 2 weeks?" Enumerators probed focal answers (e.g., 5, 10, 50) with: "Are you sure? If you do not know, you can give me your best approximation."

Practice question 2 (two months): "Assuming your current situation stays the same and you continue with your current routine and behaviors, on a scale from 0 to 100 percent, what is the percent chance that you will take your child (or go yourself, if pregnant) to the health facility in the next 2 months?" If the two month answer was less than the two week answer, enumerators stated: "As time goes by, there may be more reasons to go to the health facility, for example, for vaccination, checkups, or fever, so the chance in the next 2 months cannot be smaller than the chance in 2 weeks," and asked again.

Comprehension check: "Did you understand the example questions of percent chance? If so, what method did you like the most?" Response options: urns and balls; line with colors; both equally; did not understand percent chance; don't know; refused. Enumerators then continued the belief module using the respondent's preferred visual aid.

Current situation: "Assuming your current situation stays the same and you continue with your current routine and behaviors, on a scale from 0 to 100, what is the percent chance that your youngest child (or incoming baby if pregnant) will get malaria in the nearest rainy season?"

No doses: "For no malaria vaccine, assuming your current situation stays the same and you continue with

your current routine and behaviors, on a scale from 0 to 100, what is the percent chance your youngest child (or incoming baby if pregnant) will get malaria in the nearest rainy season, if she/he did not receive any dose of malaria vaccines?"

Only one dose: "For only one malaria vaccine, assuming your current situation stays the same and you continue with your current routine and behaviors, on a scale from 0 to 100, what is the percent chance your youngest child (or incoming baby if pregnant) will get malaria in the nearest rainy season, if she/he did receive only one malaria vaccine?"

All doses: "For all doses of malaria vaccine, assuming your current situation stays the same and you continue with your current routine and behaviors, on a scale from 0 to 100, what is the percent chance your youngest child (or incoming baby if pregnant) will get malaria in the nearest rainy season, if she/he did receive all doses of the malaria vaccine?"

Additional belief questions: The module also included: "Assuming your current situation stays the same and you continue with your current routine and behaviors, on a scale from 0 to 100, what is the percent chance that you will take your youngest child (or incoming baby if pregnant) to the health facility for the malaria vaccine in the nearest rainy season?" and "Assuming your current situation stays the same and you continue with your current routine and behaviors, on a scale from 0 to 100, what is the percent chance that the malaria vaccine will prevent malaria for your youngest child (or incoming baby if pregnant) in the nearest rainy season?"

B Measurement Diagnostics

Table A1: Mapping of elicited beliefs to model objects

Elicited object	Notation	Construction in data	Use in analysis
Central belief	p_{is}^C	Best-guess (central) response elicited before bounds; replaced by re-elicited best-guess when available	Central belief in regressions; scenario differences Δp^C
Lower bound	p_{is}^L	Reported minimum probability (if sure, set equal to central for min/max summaries)	Range and downside deviation
Upper bound	p_{is}^H	Reported maximum probability (if sure, set equal to central for min/max summaries)	Range and upside deviation
Range (imprecision)	R_{is}	$p_{is}^H - p_{is}^L$ when both bounds; $p_{is}^H - p_{is}^C$ or $p_{is}^C - p_{is}^L$ when one bound is available; 0 if sure	Imprecision dummy; range regressions; scenario differences ΔR
Upside/Downside deviations	U_{is}, D_{is}	$U_{is} = p_{is}^H - p_{is}^C$; $D_{is} = p_{is}^C - p_{is}^L$ (when bounds available)	Directional regressions
Scenario differences (central/range)	$\Delta p_{it}^C, \Delta R_{it}$	Differences in central beliefs and ranges across fixed dose transitions $s_0 \to s_1$	Structural proxy regressions
Scenario differences (bounds)	$\Delta p_{it}^L, \Delta p_{it}^H, \Delta p_{it}^M$	Differences in lower bound, upper bound, and bounds midpoint across fixed dose transitions $s_0 \to s_1$	Decision-rule model comparisons

Notes: The central belief is not constrained to equal the midpoint of the bounds. If no bound is reported and the respondent is not explicitly sure, the range is missing; those observations are excluded only from statistics that require ranges. Scenario inconsistencies are defined as invalid codes, central outside bounds (when both bounds are reported), or ranges outside [0,100].

Appendix Table A1 documents the correspondence between elicited objects, model notation, and the con-

structed variables used in the analysis.

Belief interval data quality (Appendix Table A2) is documented below. For each scenario, the table reports the number of respondents with any of four issues: (i) invalid probability codes outside $[0, 100]$, (ii) a central belief that falls outside the respondent's own reported bounds, (iii) a constructed range outside the valid support, and (iv) only one of two bounds recorded. Hard inconsistency rates are low across scenarios, between 1.4 and 1.8 percent, and respondents with any hard inconsistency are excluded from all regressions. One-bound cases are retained unless the missing bound is required by the specification.

Table A2: Belief Interval Data Quality by Scenario

Scenario	N	Invalid codes	Central outside bounds	Range outside [0,100]	One bound available	Inconsistent
Excluded: incomplete or failed understanding	36 (0.8%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Current	4335	30 (0.7%)	30 (0.7%)	26 (0.6%)	1233 (28.4%)	74 (1.7%)
No doses	4339	29 (0.7%)	29 (0.7%)	10 (0.2%)	1037 (23.9%)	62 (1.4%)
One dose	4336	21 (0.5%)	44 (1.0%)	25 (0.6%)	1041 (24.0%)	80 (1.8%)
All doses	4333	13 (0.3%)	37 (0.9%)	20 (0.5%)	1159 (26.7%)	60 (1.4%)
Any scenario	4342	78 (1.8%)	109 (2.5%)	78 (1.8%)	2220 (51.1%)	224 (5.2%)
Respondent inconsistent	4342	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	224 (5.2%)

Notes: The first row reports respondents excluded from all analysis because the malaria module was incomplete or the comprehension check was missing/invalid (malaria
_complete=0 or understand
_belief in {4,888} or missing). Scenario N counts respondents with a nonmissing central belief in that scenario after this exclusion; percentages in each column are computed relative to that scenario N. Invalid codes flag any central or bound outside [0,100], or higher/lower indicators not in {1,2} (Yes/No). Central outside bounds is evaluated only when both bounds are reported. Range is computed as max–min when both bounds are available; otherwise max–central or central–min when only one bound is available. If respondents report being sure (no higher and no lower), the lower and upper bounds are set equal to the central belief so the range is zero. Range outside [0,100] flags negative or implausibly large ranges. Inconsistent equals any invalid-code flag, central outside reported bounds, or a range outside [0,100]. One bound available indicates only one of min/max was reported and is not treated as inconsistent. Columns are not mutually exclusive; a respondent can contribute to more than one flag within a scenario. All regressions drop respondents with any scenario flagged inconsistent; one-bound cases are retained unless a statistic requires the missing bound.

Practice question ordering (Appendix Table A3) provides an additional comprehension check. Before the belief module, enumerators asked mothers two practice questions about the probability of a health facility visit within 2 weeks and within 2 months. The correct ordering requires the 2 month probability to be weakly greater than the 2 week probability. The table below reports the share of respondents providing consistent and inconsistent answers. The 90.3% consistency rate indicates strong comprehension of the probability scale. Respondents who fail the ordering check after re elicitation ($n = 420$, 9.7%) are flagged and excluded in a robustness check; see Appendix I.

Appendix Table A4 shows that heaping is most pronounced at 0, 50, and 100 for central beliefs, while bounds are less concentrated. This is consistent with a central best guess response followed by range probes, and it supports treating bounds as additional information rather than rounding noise.

Appendix Table A5 shows that booklet availability correlates weakly with beliefs. Differences are small

Table A3: Practice Examples: Ordering Check (2 Weeks vs 2 Months)

Sample	N	Both responses	Consistent (months > weeks)	Inconsistent (months ≤ weeks)	One bound available	Both missing
All analysis-eligible respondents	4347	4309 (99.1%)	3889 (90.3%)	420 (9.7%)	31 (0.7%)	7 (0.2%)

Notes: The practice questions ask for the perceived malaria risk over 2 weeks and over 2 months. The correct ordering is months > weeks. When the 2-month response was re-elicited (month_2_again), that value is used. Consistent and inconsistent shares are computed among respondents with both responses. One-bound and both-missing shares are computed over the analysis-eligible sample. Excludes respondents with incomplete malaria module or failed comprehension (malaria
_complete=0 or understand
_belief in {4,888} or missing); those are reported in Table A2.

Table A4: Heaping in reported probabilities (percent)

Scenario and belief type	N	Share 0	Share 50	Share 100	Multiple of 10[a]
Current–central	4112	181 (4.4%)	288 (7.0%)	168 (4.1%)	1863 (45.3%)
Current–min	3233	56 (1.7%)	254 (7.9%)	5 (0.2%)	1488 (46.0%)
Current–max	3302	5 (0.2%)	236 (7.1%)	56 (1.7%)	1516 (45.9%)
No–central	4115	31 (0.8%)	275 (6.7%)	573 (13.9%)	1679 (40.8%)
No–min	3118	9 (0.3%)	275 (8.8%)	10 (0.3%)	1522 (48.8%)
No–max	3160	1 (0.0%)	208 (6.6%)	134 (4.2%)	1369 (43.3%)
doses–central	4112	72 (1.8%)	453 (11.0%)	50 (1.2%)	1725 (42.0%)
doses–min	3658	18 (0.5%)	429 (11.7%)	1 (0.0%)	1576 (43.1%)
doses–max	3333	1 (0.0%)	343 (10.3%)	24 (0.7%)	1419 (42.6%)
One–central	4110	816 (19.9%)	85 (2.1%)	79 (1.9%)	1550 (37.7%)
One–min	3079	186 (6.0%)	80 (2.6%)	1 (0.0%)	1217 (39.5%)
One–max	2585	20 (0.8%)	79 (3.1%)	16 (0.6%)	1108 (42.9%)

Notes: Sample is analysis-eligible respondents after excluding inconsistent belief intervals. Shares are computed among non-missing reports. Central uses the best-guess response when available. [a] Multiples of 10 exclude 0, 50, and 100.

Table A5: Booklet availability and beliefs

Belief measure	Seen booklet	Not seen	Difference (SE)	N
Current central belief	47.67	53.26	-5.59 (1.84)	4177
No doses central belief	68.98	73.52	-4.54 (1.56)	4182
One dose central belief	48.71	47.75	0.96 (1.44)	4182
All doses central belief	23.45	21.17	2.28 (1.70)	4180
Current range	9.18	9.16	0.01 (1.00)	3943
No doses range	8.40	6.50	1.91 (0.80)	3734
One dose range	7.27	5.91	1.36 (0.71)	4049
All doses range	6.92	5.43	1.49 (0.66)	3417

Notes: Sample is analysis-eligible respondents matched to child-level booklet data; inconsistent belief intervals are excluded. Booklet seen equals card folder seen when recorded; otherwise it uses reported card ownership. Means are computed on non-missing beliefs; differences come from a linear regression of the belief measure on booklet seen with robust standard errors. Ranges use max–min when both bounds are available; otherwise max–central or central–min when only one bound is available. N varies across rows due to missing belief measures.

relative to the overall distribution, suggesting that selection into booklet observation is unlikely to drive the reduced form patterns, but it remains relevant for precision and external validity.

Appendix Table A43 pushes that comparison further by rerunning the survey outcomes on the booklet observed sample itself. The main all doses engagement coefficient changes little under that restriction, which indicates that the contrast between survey and booklet outcomes cannot be attributed mainly to sample composition.

C Index Construction and Outcome Definitions

This section collects the index construction details that are referenced in the main text so that the logic is not buried in table notes. The paper uses three summary outcomes: the preventive behavior index, the vaccination engagement index, and the all protective behavior index. The preventive behavior index aggregates seven items on mosquito net use, repellents, spraying, protective clothing, and sulfadoxine pyrimethamine, commonly called SP or Fansidar, use during current or prior pregnancy. The vaccination engagement index aggregates four items on planning to vaccinate, avoiding delays, avoiding missed appointments, and using the card or booklet to track the schedule. The all protective behavior index combines all eleven components. Appendix Table A6 reports the full behavior item distributions, and Tables A13, A14, and A15 provide additional mother level detail.

Let x_{ij} denote raw item j for mother i, where each item takes values in $\{1, 2, 3, 4\}$ after harmonizing the response categories Never, Sometimes, Most of the time, and Always. I first map each item onto the unit interval,

$$\tilde{x}_{ij} = \frac{x_{ij} - 1}{3},$$

and for items where a higher raw value reflects lower engagement, such as delays and missed appointments, I reverse the scale before proceeding. I then standardize each transformed item,

$$z_{ij} = \frac{\tilde{x}_{ij} - \bar{\tilde{x}}_j}{s_j},$$

where $\bar{\tilde{x}}_j$ and s_j are the sample mean and sample standard deviation of item j in the analysis sample.

For an index with component set J, let $z_i = (z_{ij})_{j \in J}$ and let Σ_J denote the sample covariance matrix of those standardized components. Following Anderson (2008), I use inverse covariance weights

$$w_J = \frac{\Sigma_J^{-1}\mathbf{1}}{\mathbf{1}'\Sigma_J^{-1}\mathbf{1}},$$

so that the raw index is

$$I_{iJ} = w_J' z_i.$$

The paper reports the standardized version

$$I_{iJ}^{*} = \frac{I_{iJ} - \bar{I}_J}{s(I_J)},$$

which has mean zero and standard deviation one in the estimation sample. This normalization is what allows the coefficients to be read in standard deviation units across outcome families.

Missing components are replaced by zero at the z_{ij} stage, which is the sample mean after standardization, so that an index remains defined whenever at least one component is observed. This choice preserves

sample size and keeps the outcome family aligned across specifications, but it also means that the index is a weighted summary of applicable and non applicable items rather than an average over only observed responses. Appendix I therefore reports an observed only alternative construction.

For the observed only robustness check, let $J_i^{obs} \subseteq J$ denote the subset of components observed for mother i. The alternative index is then

$$I_{iJ}^{obs} = \frac{\sum_{j \in J_i^{obs}} w_j z_{ij}}{\sum_{j \in J_i^{obs}} |w_j|},$$

followed by the same sample standardization step. This alternative keeps only observed items in the mother specific weighted sum and therefore provides a useful check on whether the baseline zero imputation rule is driving the main patterns.

The lower N on the sulfadoxine pyrimethamine, or SP or Fansidar, components is a feature of item applicability, not a data error. Those items are only relevant for currently pregnant respondents or for retrospective reports on the last pregnancy, so they apply to smaller subpopulations than the net use or appointment tracking items. This is precisely why the lower N issue is noted in the main text. The summary indices are useful because they reduce dimensionality and the multiple testing burden, but their interpretation requires remembering that the components are not uniformly applicable across respondents.

D Booklet Verification, Sample Eligibility, and Administrative Constraints

The booklet outcomes are the most credible baseline source on realized malaria vaccination timing in this project. Enumerators transcribed dates directly from the child health booklet, photographed the relevant pages, and the data team audited the transcriptions against those images. The booklet analysis is therefore based on a verified record source rather than on recalled vaccination history alone.

The smaller booklet sample should not be interpreted as generic missingness or attrition. Booklet based malaria vaccine outcomes are only meaningful for respondents whose child had already been born and had reached the relevant age window for malaria vaccine history to exist. Pregnant respondents and very young children may not yet have a meaningful vaccine history window, and some households were interviewed before the child's malaria vaccine record could have been generated. The booklet sample is thus an eligibility defined analytic subsample. The relevant table notes in the paper follow this interpretation.

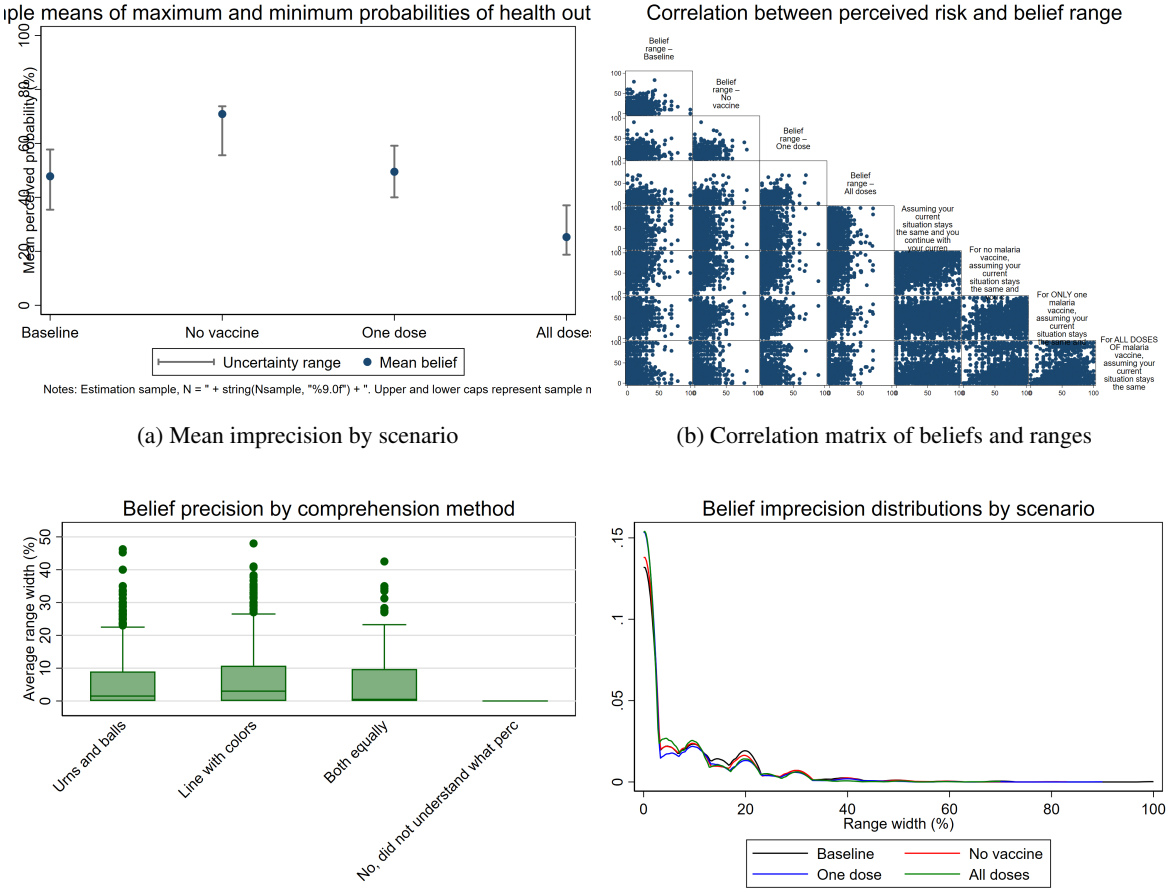
Administrative linkage is also incomplete at baseline for reasons that do not undermine the credibility of the booklet record itself. Baseline facility data were not yet consistently linkable at the child level because identification numbers were not always recorded in a way that allowed clean matching across facilities, migration across catchment areas complicated follow-up, and the available baseline administrative aggregates did not track individual children with the precision needed for the present analysis. Those limitations are why the booklet remains the primary source for realized dose timing at baseline. Later study rounds can use improved linkage and a longer observation window to strengthen the administrative side of the design.

E Additional Descriptive Tables and Figures

Tables

These appendix tables provide additional detail on belief distributions, conditional imprecision, and the construction of behavior indices. They confirm that imprecision is concentrated in a subset of respondents and that malaria vaccination engagement is distinct from general prevention behavior, motivating the separate outcome indices in the main text.

Figures



(a) Mean imprecision by scenario

(b) Correlation matrix of beliefs and ranges

(c) Imprecision by comprehension

(d) Distribution of belief ranges

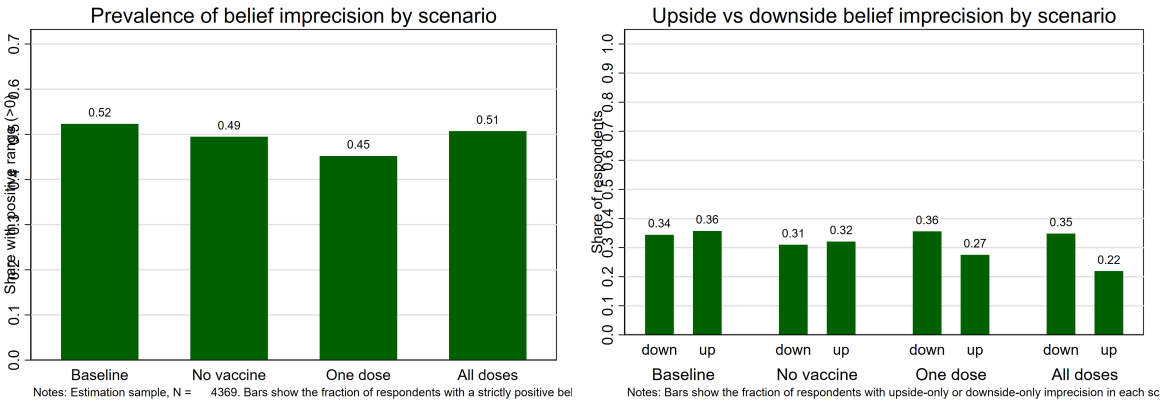
Figure A7: Additional descriptive patterns in imprecision and comprehension

The appendix figures show that imprecision is right skewed and scenario dependent, with lower ranges near probability extremes and higher ranges in the interior of the belief distribution. The up/down plots reinforce the asymmetry between downside and upside uncertainty.

Table A6: Summary statistics: perceived infection risk and belief imprecision

Variable	N	Mean	SD	P1	P5	P10	P25	P50	P75	P90	P95	P99	Min	Max
Central belief: current	4112	48.65	27.21	0.00	3.00	10.00	30.00	50.00	70.00	87.00	95.00	100.00	0.00	100.00
Central belief: no doses	4115	69.76	24.68	5.00	20.00	33.00	50.00	75.00	90.00	100.00	100.00	100.00	0.00	100.00
Central belief: one dose	4112	48.62	21.23	0.00	10.00	20.00	35.00	50.00	60.00	76.00	85.00	100.00	0.00	100.00
Central belief: all doses	4110	23.45	25.55	0.00	0.00	0.00	5.00	15.00	30.00	60.00	87.00	100.00	0.00	100.00
Imprecision (range): current	3856	8.59	12.50	0.00	0.00	0.00	0.00	2.00	15.00	25.00	30.00	56.00	0.00	100.00
Imprecision (range): no doses	3631	7.95	11.92	0.00	0.00	0.00	0.00	0.00	12.00	24.00	30.00	50.00	0.00	90.00
Imprecision (range): one dose	3982	6.98	11.40	0.00	0.00	0.00	0.00	0.00	10.00	20.00	30.00	50.00	0.00	90.00
Imprecision (range): all doses	3371	6.67	10.22	0.00	0.00	0.00	0.00	0.00	10.00	20.00	30.00	47.00	0.00	90.00

Notes: Sample includes analysis-eligible respondents after excluding incomplete comprehension and any inconsistent interval reports. Imprecision uses the available bound(s): max–min when both bounds are reported, otherwise max–central or central–min when only one bound is available. One-bound cases are retained and contribute when the relevant bound is available.



(a) Share with positive imprecision by scenario

(b) Upward vs downward imprecision by scenario

Figure A8: Imprecision prevalence and direction by scenario

Notes: Left panel: share of respondents reporting a positive belief range (at least one bound different from the central belief) by vaccination scenario. Right panel: share of imprecise respondents whose upper bound exceeds their central belief (upside imprecision) vs. whose lower bound is below their central belief (downside imprecision), by scenario. Shares are computed among all analysis eligible respondents ($N = 4{,}347$). "Any scenario" denotes imprecision in at least one of the four scenarios.

Table A7: Summary statistics: behavior items

Survey item	Never	Sometimes	Most of the time	Always	N
Preventive behavior items					
You slept under a mosquito net during the last week	17.7	6.0	6.1	70.1	4116
Your youngest child slept under a mosquito net during the last week	19.0	6.2	4.7	70.2	2458
You used mosquito repellent (e.g., cream, coils, sprays) during the last week	61.4	20.9	8.6	9.0	4114
You sprayed or fumigated the inside of the house to kill mosquitoes (e.g., indoor spraying)	78.2	15.9	4.4	1.5	4119
You wore long-sleeved shirts or long trousers to protect from mosquitoes during the last week	57.1	21.7	9.5	11.8	4110
During this pregnancy, you took SP/Fansidar to prevent malaria	20.4	26.3	17.5	35.8	1647
During your last pregnancy, you took SP/Fansidar to prevent malaria	4.9	17.9	24.7	52.5	2453
Vaccination engagement items					
You plan to bring your youngest child/incoming baby for the malaria vaccine	1.4	4.8	7.1	86.6	4112
You sometimes delay a scheduled malaria vaccine appointment	77.9	18.3	1.3	2.5	4101
You sometimes miss a scheduled malaria vaccine appointment	83.1	14.1	0.8	1.9	4088
You use a vaccination card or child health record to track the schedule	12.9	14.8	11.2	61.1	4065

Notes: Percentages are computed over responses coded into the harmonized categories Never, Sometimes, Most of the time, and Always. DK/Refused responses are excluded from the denominator. Appointment-delay and appointment-miss items are reverse-coded when constructing the engagement index.

Table A8: Summary statistics: standardized behavior indices

Index	N	Mean	SD	P1	P5	P10	P25	P50	P75	P90	P95	P99	Min	Max
Preventive behavior index	4122	0.00	1.00	-2.41	-1.61	-1.39	-0.78	0.07	0.68	1.18	1.49	2.11	-3.28	3.11
Vaccine engagement index	4120	0.00	1.00	-3.06	-2.10	-1.35	-0.62	0.33	0.80	0.80	0.80	0.80	-6.09	0.80
All protective behavior index	4122	0.00	1.00	-2.63	-1.71	-1.32	-0.69	0.08	0.76	1.29	1.50	2.01	-4.24	3.01

Notes: Indices use Anderson (2008) inverse-covariance weights applied to standardized components; missing components are set to zero (the sample mean) so indices are defined when at least one component is observed, and the resulting index is re-standardized to mean 0 and standard deviation 1. See Appendix C for the full construction details and the discussion of pregnancy-specific items with lower effective N.

Table A9: Correlation of Uncertainty Across Scenarios

	Current	No doses	One dose	All doses
Panel A: Range correlations (Pearson)				
Current	1.00	0.53	0.47	0.46
No doses	0.53	1.00	0.57	0.53
One dose	0.47	0.57	1.00	0.59
All doses	0.46	0.53	0.59	1.00
Panel B: Range correlations (Spearman)				
Current	1.00	0.62	0.58	0.57
No doses	0.62	1.00	0.63	0.62
One dose	0.58	0.63	1.00	0.66
All doses	0.57	0.62	0.66	1.00
Panel C: Uncertain indicator correlations				
Current	1.00	0.60	0.57	0.55
No doses	0.60	1.00	0.60	0.59
One dose	0.57	0.60	1.00	0.61
All doses	0.55	0.59	0.61	1.00

Notes: Sample is analysis-eligible respondents (malaria module complete and comprehension not missing/invalid). N=4347. Panel A uses Pearson correlations for ranges; pairwise N ranges from 3559 to 3559. Panel B uses Spearman rank correlations; pairwise N ranges from 3559 to 3559. Panel C reports Pearson correlations for the uncertainty indicator; pairwise N ranges from 3559 to 3559. Ranges use max–min when both bounds are available, otherwise max–central or central–min when only one bound is available. If respondents report being sure (no higher and no lower), bounds are set equal to the central belief so the range is zero. If no bound is reported and the respondent is not explicitly sure, the range is missing. Values outside [0,100] or inconsistent scenarios (invalid codes or central outside bounds) are treated as missing for that scenario. The uncertainty indicator equals 1 when the range is positive; a range of 0 denotes certainty. Scenario-level N for ranges: current=3998, no doses=3777, one dose=4121, all doses=3514. Pairwise N is smaller because a correlation requires nonmissing ranges in both scenarios.

Table A10: Correlations of subjective infection probabilities and behavior

Panel A: Minimum and maximum beliefs

	Current min	Current max	No doses min	No doses max	One dose min	One dose max	All doses min	All doses max	Behavior index
Current min	1.00	–	–	–	–	–	–	–	–
Current max	0.87	1.00	–	–	–	–	–	–	–
No doses min	0.41	0.28	1.00	–	–	–	–	–	–
No doses max	0.32	0.37	0.87	1.00	–	–	–	–	–
One dose min	0.25	0.16	0.43	0.35	1.00	–	–	–	–
One dose max	0.11	0.22	0.28	0.39	0.83	1.00	–	–	–
All doses min	0.08	0.02	0.02	-0.05	0.27	0.22	1.00	–	–
All doses max	-0.01	0.09	-0.09	-0.01	0.16	0.29	0.91	1.00	–
All protective behavior index	-0.07	-0.06	0.02	0.01	0.03	0.03	-0.06	-0.08	1.00

Panel B: Central beliefs

	Current central	No doses central	One dose central	All doses central	Behavior index
Current central	1.00	–	–	–	–
No doses central	0.38	1.00	–	–	–
One dose central	0.21	0.39	1.00	–	–
All doses central	0.07	-0.01	0.27	1.00	–
All protective behavior index	-0.09	-0.00	0.03	-0.05	1.00

Panel C: Central beliefs vs bounds (within scenario)

Scenario	Corr(central, min)	Corr(central, max)
Current	0.93	0.95
No doses	0.92	0.96
One dose	0.92	0.95
All doses	0.95	0.97

Notes: Sample is analysis-eligible respondents. Panel A uses minimum and maximum beliefs; respondents who report being sure (no higher and no lower) have min and max set equal to the central belief, while other missing bounds remain missing. Panel B uses central beliefs. Scenarios flagged inconsistent are excluded. Pairwise N ranges from 2679 to 2679 in Panel A and from 4110 to 4110 in Panel B. Panel C reports correlations between central beliefs and bounds within each scenario; pairwise N ranges from 3079 to 3658 for central–min and from 2585 to 3333 for central–max. The behavior index is the all protective behavior index (Anderson 2008 weights).

Table A11: Uncertainty Patterns Across Scenarios

Current	No doses	One dose	All doses	Count	Share (%)
C	C	C	C	890	30.1
C	C	C	U	90	3.0
C	C	U	C	36	1.2
C	C	U	U	52	1.8
C	U	C	C	58	2.0
C	U	C	U	39	1.3
C	U	U	C	41	1.4
C	U	U	U	95	3.2
U	C	C	C	113	3.8
U	C	C	U	63	2.1
U	C	U	C	71	2.4
U	C	U	U	98	3.3
U	U	C	C	91	3.1
U	U	C	U	142	4.8
U	U	U	C	112	3.8
U	U	U	U	962	32.6

Notes: Sample is analysis-eligible respondents (malaria module complete and comprehension not missing/invalid) with nonmissing ranges in all four scenarios. N=2953. The table reports the pattern of uncertainty across scenarios where U denotes a positive range and C denotes a zero range. Range is defined as max–min when both bounds are available; otherwise max–central or central–min when only one bound is available. If no bounds are reported and the respondent is not explicitly sure, the range is missing and the observation is excluded from the pattern sample. Scenarios with invalid codes or central outside bounds are treated as inconsistent and their ranges are set to missing.

Table A12: Conditional Uncertainty Across Scenarios

Anchor group	Current	No doses	One dose	All doses
Panel A: Pr(uncertain_j — group)				
Current scenario (Uncertain)	100.0	77.3	72.8	75.8
Current scenario (Certain)	0.0	17.0	16.2	21.1
No doses scenario (Uncertain)	84.7	100.0	76.9	80.6
No doses scenario (Certain)	24.9	0.0	17.2	21.7
One dose scenario (Uncertain)	83.1	81.3	100.0	82.5
One dose scenario (Certain)	26.2	21.4	0.0	21.2
All doses scenario (Uncertain)	80.6	79.9	78.0	100.0
All doses scenario (Certain)	26.2	21.0	16.9	0.0
Panel B: Mean range (percentage points)				
Current scenario (Uncertain)	16.6	13.0	11.9	10.7
Current scenario (Certain)	0.0	2.4	2.2	2.4
No doses scenario (Uncertain)	14.7	16.4	12.8	11.7
No doses scenario (Certain)	3.4	0.0	1.9	2.1
One dose scenario (Uncertain)	14.4	13.8	15.8	12.1
One dose scenario (Certain)	3.8	3.0	0.0	2.0
All doses scenario (Uncertain)	13.8	13.6	13.0	13.6
All doses scenario (Certain)	3.5	2.7	2.1	0.0
Panel C: Median range (percentage points)				
Current scenario (Uncertain)	14.0	10.0	10.0	8.0
Current scenario (Certain)	0.0	0.0	0.0	0.0
No doses scenario (Uncertain)	10.0	13.0	10.0	10.0
No doses scenario (Certain)	0.0	0.0	0.0	0.0
One dose scenario (Uncertain)	10.0	10.0	11.0	10.0
One dose scenario (Certain)	0.0	0.0	0.0	0.0
All doses scenario (Uncertain)	10.0	10.0	10.0	10.0
All doses scenario (Certain)	0.0	0.0	0.0	0.0

Notes: Sample is analysis-eligible respondents (malaria module complete and comprehension not missing/invalid). N=4347. Anchor Ns (nonmissing ranges): Current=3998, No doses=3777, One dose=4121, All doses=3514. Ranges use max–min when both bounds are reported, otherwise max–central or central–min when only one bound is available. If respondents report being sure (no higher and no lower), bounds are set equal to the central belief so the range is zero. If no bound is reported and the respondent is not explicitly sure, the range is missing; values outside [0,100] or inconsistent scenarios (invalid codes or central outside bounds) are treated as missing. Uncertain is defined as range > 0 and certain as range $= 0$; both are defined only for nonmissing ranges. Values in Panel A are percentages. Panels B and C report mean and median range in percentage points, respectively.

Table A13: Mother level preventive behavior items

Vaccine dose	Any cov	All cov	Any within	All within
Panel A: Routine (non-malaria) vaccines				
BCG	86.3	77.8	52.2	39.2
OPV0	64.7	51.6	59.0	46.2
Hepatitis B	2.1	1.3	1.5	1.0
OPV1	86.1	79.4	37.3	28.4
OPV2	82.2	75.1	22.5	17.3
OPV3	75.6	67.8	15.3	12.7
Pentavalent 1	88.3	82.1	42.9	33.6
Pentavalent 2	85.5	79.0	27.0	21.3
Pentavalent 3	80.4	74.0	18.3	15.1
PCV1	88.4	82.2	42.6	33.4
PCV2	85.2	78.7	27.0	21.2
PCV3	80.5	74.1	18.1	14.9
Rotavirus 1	84.6	77.4	35.8	26.5
Rotavirus 2	79.3	71.6	21.0	16.0
Rotavirus 3	38.2	32.5	8.0	6.5
IPV	79.0	72.4	17.5	14.5
Vitamin A 1	76.2	75.2	31.6	31.1
Vitamin A 2	73.3	73.0	38.7	38.5
Vitamin A 3	65.4	64.9	27.1	27.0
Measles 1	82.9	82.6	35.5	35.1
Measles 2	76.7	76.2	36.4	36.3
Yellow fever	81.2	80.9	31.2	30.8
Meningococcal	75.1	74.6	30.7	30.6
Panel B: Malaria vaccine doses				
Malaria dose 1	71.9	71.0	27.0	26.5
Malaria dose 2	70.2	69.7	16.4	16.2
Malaria dose 3	67.8	67.4	25.0	24.8
Malaria dose 4	60.4	60.0	27.3	27.2

Notes: Mean values of individual indicators entering the preventive behavior component of the all protective behavior index, for mother level outcomes. Indicators are binary (0/1). Coverage and timing statistics computed from vaccination records verified against health booklets. Sample: mothers with a valid child health booklet who received at least one malaria dose.

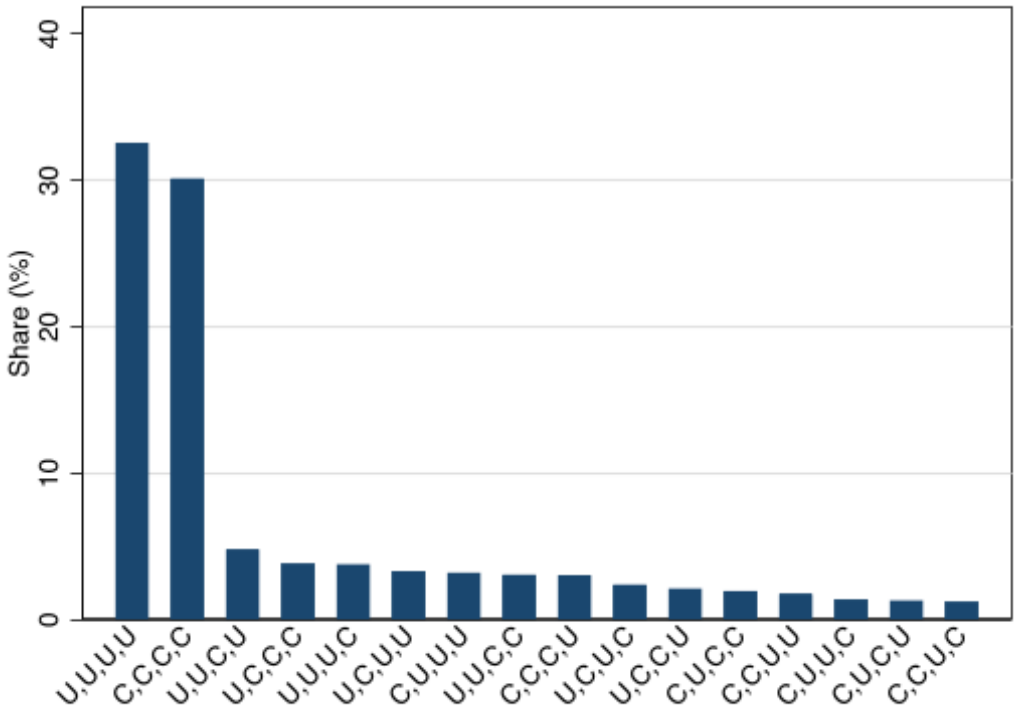


Figure A9: Distribution of range patterns across scenarios (U = range > 0, C = range $= 0$; order: current, no doses, one dose, all doses)

Table A14: Mother level vaccination engagement items

Indicator	Mean (%)	N
Panel A: All vaccines		
Any coverage (all vaccines)	91.3	3429
All coverage (all vaccines)	0.5	3429
Any within-schedule (all vaccines)	80.6	3429
All within-schedule (all vaccines)	0.3	3429
Panel B: Routine (non-malaria) vaccines		
Any coverage (non-malaria)	91.3	3429
All coverage (non-malaria)	0.5	3429
Any within-schedule (non-malaria)	80.5	3429
All within-schedule (non-malaria)	0.3	3429
Panel C: Malaria vaccine doses		
Any coverage (malaria)	72.7	1856
All coverage (malaria)	57.8	1856
Any within-schedule (malaria)	46.4	1856
All within-schedule (malaria)	5.7	1856

Notes: Mean values of the 12 items entering the Anderson (2008) inverse covariance weighted vaccination engagement index (mother-level aggregates). Column "Mean (%)" is the sample mean in percentage points; N varies by item due to missing records. Items are classified as: on-time vaccination (4 items), knowledge of vaccine schedule (3 items), appointment adherence (3 items), and record use (2 items).

Table A15: Mother level coverage and timing aggregates

Measure	Mean	SD	P25	P50	P75
Number of children	1.31	0.48	1.00	1.00	2.00
Total doses due (all vaccines)	22.48	12.81	11.00	27.00	30.00
Total doses received (all vaccines)	15.76	11.67	5.00	14.00	25.00
Total doses on time (all vaccines)	5.96	6.43	1.00	4.00	9.00
Total doses due (non-malaria)	20.33	11.07	11.00	23.00	26.00
Total doses received (non-malaria)	14.32	10.21	5.00	14.00	21.00
Total doses on time (non-malaria)	5.45	5.90	1.00	3.00	8.00
Total malaria doses due	2.15	2.03	0.00	4.00	4.00
Total malaria doses received	1.45	1.87	0.00	0.00	4.00
Total malaria doses on time	0.51	1.02	0.00	0.00	1.00
Share received (all vaccines)	0.66	0.30	0.53	0.77	0.88
Share on time (all vaccines)	0.29	0.27	0.06	0.22	0.45
Share received (non-malaria)	0.66	0.29	0.55	0.78	0.88
Share on time (non-malaria)	0.29	0.27	0.06	0.21	0.46
Share received (malaria)	0.67	0.44	0.00	1.00	1.00
Share on time (malaria)	0.24	0.31	0.00	0.00	0.50

Notes: Mother level vaccination coverage and within window timing statistics from health booklets. “Share received” is the fraction of scheduled malaria doses actually recorded in the booklet. “Share on time” is the fraction of received doses administered within the World Health Organization recommended age window. P25, P50, P75 are quartiles. Sample: mothers with a valid child health booklet.

Table A16: Child level dose timing outcomes

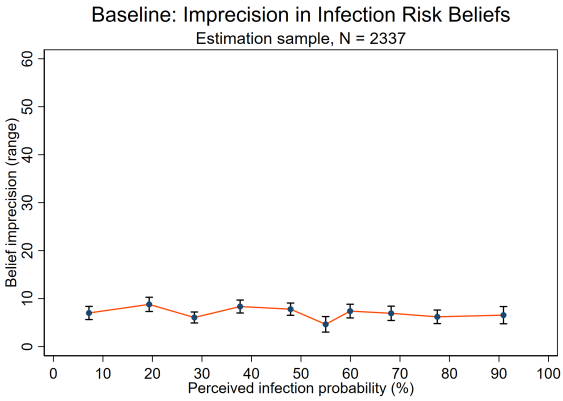
Vaccine dose	Too early	Within	Late	Very late
Panel A: Routine (non-malaria) vaccines				
BCG timing status	0.0	10.2	45.6	44.3
OPV0 timing status	0.0	26.0	65.4	8.6
Hepatitis B timing status	0.0	52.9	27.9	19.1
OPV1 timing status	2.7	36.9	37.4	23.0
OPV2 timing status	2.4	22.9	37.6	37.0
OPV3 timing status	1.7	17.8	51.2	29.3
Pentavalent 1 timing status	2.8	41.6	39.8	15.8
Pentavalent 2 timing status	2.7	26.6	42.7	28.1
Pentavalent 3 timing status	2.0	19.7	54.2	24.2
PCV1 timing status	2.8	41.4	39.8	16.0
PCV2 timing status	2.7	26.5	42.6	28.1
PCV3 timing status	1.9	19.4	53.9	24.8
Rotavirus 1 timing status	2.8	35.5	35.9	25.8
Rotavirus 2 timing status	2.3	22.2	36.3	39.1
Rotavirus 3 timing status	2.1	20.7	51.2	26.0
IPV timing status	1.8	19.3	54.3	24.5
Vitamin A 1 timing status	3.1	38.7	36.1	22.1
Vitamin A 2 timing status	3.4	49.6	20.1	26.9
Vitamin A 3 timing status	3.1	38.5	22.0	36.4
Measles 1 timing status	3.2	39.9	25.1	31.8
Measles 2 timing status	5.1	43.3	20.6	31.0
Yellow fever timing status	3.2	35.4	23.1	38.3
Meningococcal timing status	3.9	37.7	20.9	37.5
Panel B: Malaria vaccine doses				
Malaria dose 1 timing status	3.6	34.5	33.3	28.6
Malaria dose 2 timing status	2.0	21.4	33.7	42.9
Malaria dose 3 timing status	2.4	34.5	24.1	39.0
Malaria dose 4 timing status	3.9	41.6	19.0	35.5

Notes: Distribution of malaria vaccine dose timing status for children in the booklet sample. Timing categories: “Too early” (administered before the recommended minimum age), “Within” (within the recommended age window), “Late” (after the window but within 3 months), “Very late” (more than 3 months past the window close). Shares sum to 100% within each dose row. Only doses 3 and 4 are shown because doses 1 and 2 overlap with the Expanded Programme on Immunization schedule and have higher on-time rates. Sample: children with a valid malaria vaccination booklet entry.

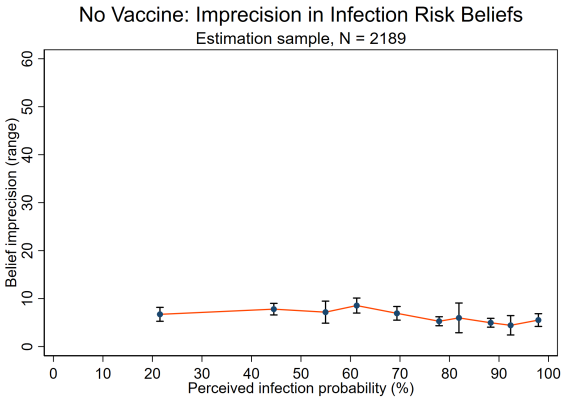
Table A17: Child level dose coverage outcomes

Vaccine dose	No (0)	Yes (100)
Panel A: Routine (non-malaria) vaccines		
BCG vaccinated	18.5	81.5
OPV0 vaccinated	42.5	57.5
Hepatitis B vaccinated	98.4	1.6
OPV1 vaccinated	17.4	82.6
OPV2 vaccinated	22.0	78.0
OPV3 vaccinated	29.4	70.6
Pentavalent 1 vaccinated	15.0	85.0
Pentavalent 2 vaccinated	18.4	81.6
Pentavalent 3 vaccinated	23.6	76.4
PCV1 vaccinated	14.9	85.1
PCV2 vaccinated	18.7	81.3
PCV3 vaccinated	23.5	76.5
Rotavirus 1 vaccinated	19.1	80.9
Rotavirus 2 vaccinated	25.1	74.9
Rotavirus 3 vaccinated	65.6	34.4
IPV vaccinated	25.2	74.8
Vitamin A 1 vaccinated	24.4	75.6
Vitamin A 2 vaccinated	26.9	73.1
Vitamin A 3 vaccinated	34.9	65.1
Measles 1 vaccinated	17.3	82.7
Measles 2 vaccinated	23.7	76.3
Yellow fever vaccinated	19.0	81.0
Meningococcal vaccinated	25.3	74.7
Panel B: Malaria vaccine doses		
Malaria dose 1 vaccinated	28.8	71.2
Malaria dose 2 vaccinated	30.1	69.9
Malaria dose 3 vaccinated	32.5	67.5
Malaria dose 4 vaccinated	39.8	60.2

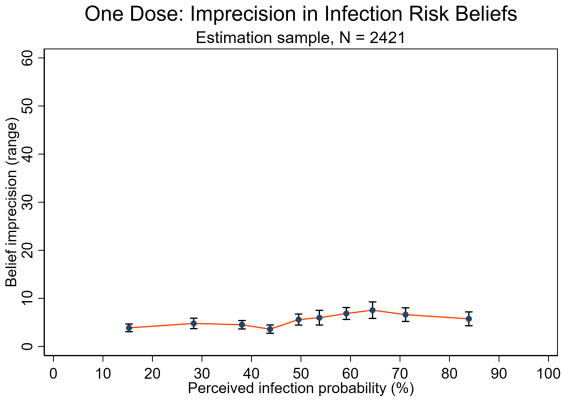
Notes: Coverage rates (percentage vaccinated, No/Yes) for malaria vaccine doses 3 and 4 from the child health booklet sample. The baseline first dose completion rate is approximately 67%, reflecting the early stage of the malaria vaccine rollout at the time of data collection.



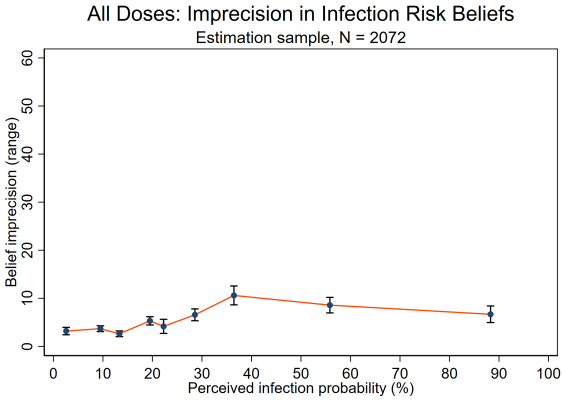
(a) Current



(b) No doses

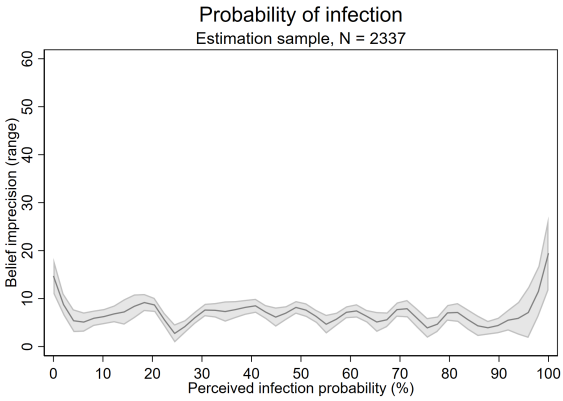


(c) One dose

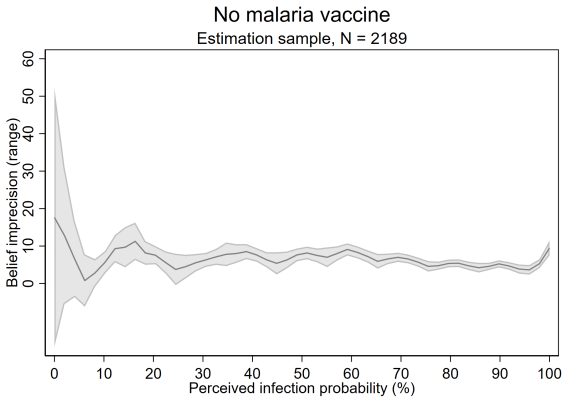


(d) All doses

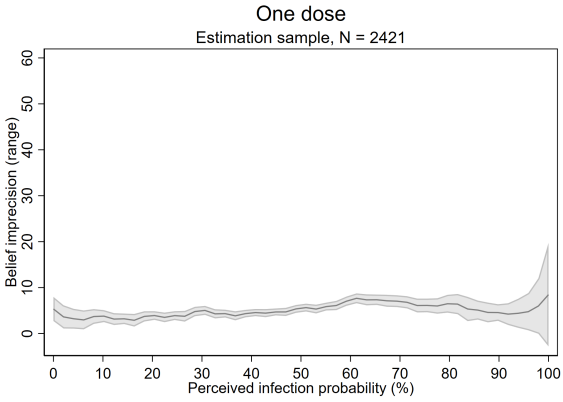
Figure A10: Binned imprecision vs belief by scenario



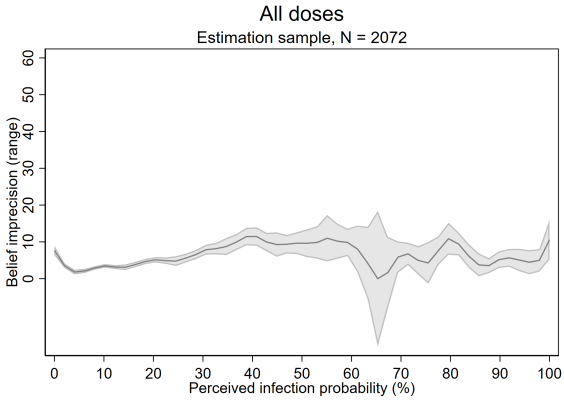
(a) Current



(b) No doses

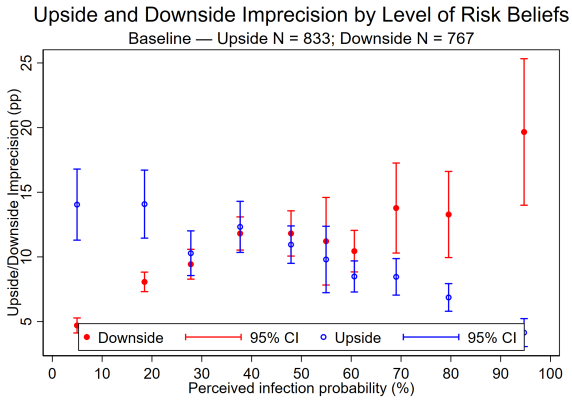


(c) One dose

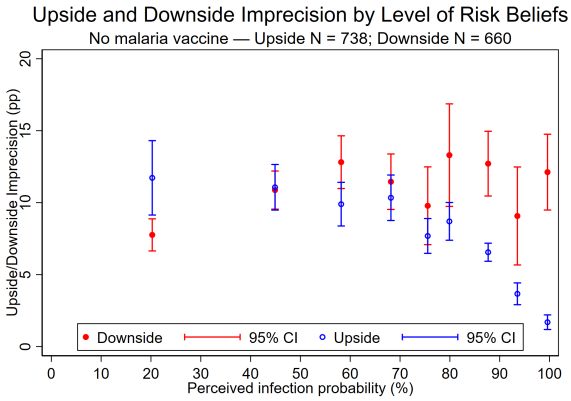


(d) All doses

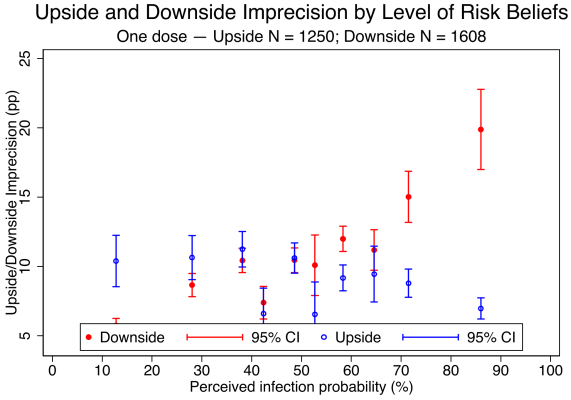
Figure A11: Kernel imprecision vs belief by scenario



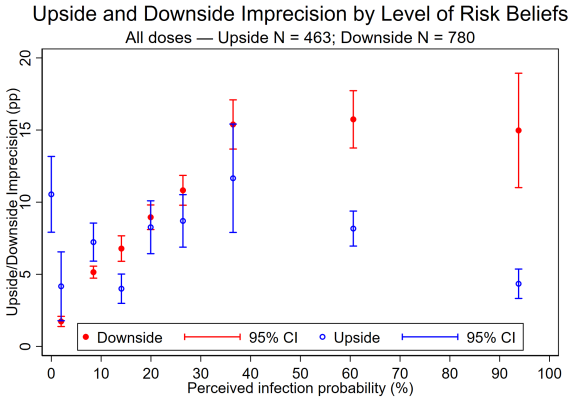
(a) Current



(b) No doses



(c) One dose



(d) All doses

Figure A12: Upside and downside imprecision by scenario

F Continuous Range Regressions: Intentional Behavior

Table A18: Range regressions by scenario (behavior indices)

Panel A: Current scenario

	No central belief	Central belief included				
	(1)	(2)	(3)	(4)	(5)	(6)
	Preventive behavior	Vaccine engagement	All protective behavior	Prot. behav.	Vaccination behav.	All malaria behav.
Range (current)	-0.004***	0.002	-0.003**	-0.004***	0.002	-0.003*
	(0.001)	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)
Current risk	–	–	–	-0.001	-0.004***	-0.002***
	–	–	–	(0.001)	(0.001)	(0.001)
N	3843	3842	3843	3843	3842	3843
R-squared	0.131	0.115	0.123	0.131	0.122	0.126

Panel B: No doses scenario

	No central belief	Central belief included				
	(1)	(2)	(3)	(4)	(5)	(6)
	Preventive behavior	Vaccine engagement	All protective behavior	Prot. behav.	Vaccination behav.	All malaria behav.
Range (no doses)	-0.005***	0.000	-0.004**	-0.005***	0.000	-0.004**
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Risk (no doses)	–	–	–	-0.001	-0.001	-0.001
	–	–	–	(0.001)	(0.001)	(0.001)
N	3619	3617	3619	3619	3617	3619
R-squared	0.130	0.111	0.122	0.130	0.112	0.123

Panel C: One dose scenario

	No central belief	Central belief included				
	(1)	(2)	(3)	(4)	(5)	(6)
	Preventive behavior	Vaccine engagement	All protective behavior	Prot. behav.	Vaccination behav.	All malaria behav.
Range (one dose)	-0.001	0.001	-0.000	-0.001	0.001	-0.001
	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)
Risk (one dose)	–	–	–	0.000	-0.001	0.000
	–	–	–	(0.001)	(0.001)	(0.001)
N	3970	3968	3970	3970	3968	3970
R-squared	0.126	0.115	0.124	0.126	0.115	0.124

Panel D: All doses scenario

	No central belief	Central belief included				
	(1)	(2)	(3)	(4)	(5)	(6)
	Preventive behavior	Vaccine engagement	All protective behavior	Prot. behav.	Vaccination behav.	All malaria behav.
Range (all doses)	-0.000	0.003	0.001	0.001	0.005	0.003
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Risk (all doses)	–	–	–	-0.002**	-0.004***	-0.004***
	–	–	–	(0.001)	(0.001)	(0.001)
N	3359	3358	3359	3359	3358	3359
R-squared	0.131	0.136	0.129	0.133	0.144	0.135

Notes: Outcomes are standardized behavior indices (mean 0, sd 1; Anderson 2008 weights). Panels report regressions of outcomes on the continuous range for each scenario. Columns 1–3 exclude the scenario-specific central belief; columns 4–6 include it. All regressions include health-facility fixed effects and cluster standard errors at the facility. Inconsistent intervals (invalid codes, central outside bounds when both bounds are reported, or range outside [0,100]) are excluded; missing bounds yield missing ranges and only affect specifications that require them.

Continuous range coefficients are small and imprecise across all three indices, consistent with weak associations in the reduced form binary specifications. Central beliefs are negative in higher protection scenarios,

while range coefficients remain near zero.

G Booklet Outcomes: Youngest Child

Table A19: Youngest child booklet outcomes and imprecision

Scenario	Term	Within	Share	Any within	All within	Any cov.	All cov.	Dose1	Dose2	Dose3	Dose4
Panel A: Imprecision dummy only											
Current	Imprecision	-0.005 (0.027)	-2.474 (2.839)	-0.765 (4.783)	-5.044** (2.221)	2.203 (4.823)	-0.912 (4.612)	-2.921 (3.797)	-5.618 (3.394)	-3.266 (4.079)	5.060 (4.706)
Current	N	3014	764	764	764	764	764	764	726	724	684
No doses	Imprecision	-0.017 (0.030)	-3.704 (3.146)	-5.909 (4.927)	-3.182 (2.305)	1.761 (4.925)	-2.290 (4.661)	-5.889 (4.585)	-6.392 (4.233)	-0.011 (3.997)	-2.353 (4.295)
No doses	N	2852	712	712	712	712	712	712	678	677	641
One dose	Imprecision	0.044 (0.030)	2.757 (2.917)	5.131 (4.454)	1.316 (2.287)	5.300 (4.126)	-0.323 (4.084)	0.445 (4.293)	-2.016 (3.768)	8.589** (3.670)	6.374* (3.515)
One dose	N	3100	782	782	782	782	782	782	741	739	699
All doses	Imprecision	0.032 (0.024)	2.729 (2.585)	3.767 (3.870)	1.539 (2.405)	7.777** (3.690)	6.818* (4.110)	0.626 (3.995)	-2.345 (3.632)	5.659 (4.432)	4.573 (4.535)
All doses	N	2620	642	642	642	642	642	642	608	607	577
Panel B: Imprecision + central belief											
Current	Imprecision	-0.005 (0.027)	-2.685 (2.873)	-0.654 (4.806)	-5.150** (2.203)	2.055 (4.820)	-1.403 (4.624)	-3.158 (3.794)	-6.237* (3.416)	-3.311 (4.156)	5.036 (4.740)
Current	Central	-0.000 (0.001)	-0.037 (0.054)	0.020 (0.089)	-0.019 (0.038)	-0.026 (0.075)	-0.087 (0.075)	-0.042 (0.072)	-0.123* (0.072)	-0.009 (0.077)	-0.005 (0.084)
Current	N	3014	764	764	764	764	764	764	726	724	684
No doses	Imprecision	-0.017 (0.030)	-3.778 (3.125)	-5.951 (4.918)	-3.271 (2.287)	1.713 (4.932)	-2.384 (4.655)	-5.938 (4.586)	-6.445 (4.160)	-0.025 (3.999)	-2.361 (4.272)
No doses	Central	-0.000 (0.001)	-0.072 (0.061)	-0.041 (0.092)	-0.085 (0.055)	-0.046 (0.100)	-0.090 (0.105)	-0.047 (0.080)	-0.150* (0.080)	-0.049 (0.084)	-0.103 (0.098)
No doses	N	2852	712	712	712	712	712	712	678	677	641
One dose	Imprecision	0.045 (0.030)	2.775 (2.924)	5.150 (4.503)	1.318 (2.288)	5.299 (4.130)	-0.316 (4.074)	0.467 (4.301)	-1.932 (3.792)	8.701** (3.689)	6.517* (3.510)
One dose	Central	-0.001 (0.001)	-0.163** (0.063)	-0.177 (0.107)	-0.023 (0.049)	0.002 (0.088)	-0.064 (0.104)	-0.204** (0.101)	-0.153** (0.068)	-0.183** (0.080)	-0.161 (0.107)
One dose	N	3100	782	782	782	782	782	782	741	739	699
All doses	Imprecision	0.033 (0.024)	2.745 (2.595)	3.840 (3.831)	1.398 (2.418)	7.858** (3.701)	7.092* (4.112)	0.799 (4.006)	-2.305 (3.660)	5.353 (4.381)	4.648 (4.533)
All doses	Central	0.000 (0.001)	-0.010 (0.066)	-0.045 (0.105)	0.086 (0.074)	-0.050 (0.081)	-0.168* (0.087)	-0.106 (0.096)	-0.017 (0.091)	0.131 (0.091)	-0.045 (0.103)
All doses	N	2620	642	642	642	642	642	642	608	607	577
Panel C: Upside/Downside + central											
Current	Upside	-0.007 (0.027)	-1.592 (2.783)	0.658 (5.028)	-1.867 (2.075)	2.299 (4.063)	-0.760 (4.989)	-3.713 (4.153)	-5.911 (3.603)	-0.756 (3.903)	6.907 (4.737)
Current	Downside	-0.017 (0.028)	-2.747 (2.702)	-2.671 (5.200)	-4.138* (2.216)	0.899 (4.672)	-2.883 (4.457)	-0.423 (3.577)	-5.345 (3.822)	-1.613 (3.929)	-3.913 (4.701)
Current	Central	-0.000 (0.001)	-0.033 (0.054)	0.022 (0.089)	-0.010 (0.037)	-0.028 (0.075)	-0.084 (0.075)	-0.040 (0.072)	-0.116 (0.073)	-0.004 (0.078)	-0.003 (0.084)
Current	N	3014	764	764	764	764	764	764	726	724	684
No doses	Upside	0.006 (0.031)	-1.134 (3.564)	-3.389 (5.005)	-2.458 (2.384)	2.655 (4.316)	0.918 (5.164)	-2.395 (4.929)	-1.363 (4.395)	4.492 (4.204)	-3.403 (5.396)
No doses	Downside	-0.033 (0.028)	-3.151 (2.937)	-3.561 (5.236)	-0.948 (2.240)	-2.683 (4.211)	-4.604 (4.108)	-6.500 (4.337)	-9.439** (3.927)	1.265 (4.180)	1.505 (4.746)
No doses	Central	-0.000 (0.001)	-0.074 (0.062)	-0.050 (0.094)	-0.092 (0.056)	-0.039 (0.099)	-0.087 (0.104)	-0.053 (0.081)	-0.153* (0.081)	-0.036 (0.085)	-0.112 (0.101)
No doses	N	2852	712	712	712	712	712	712	678	677	641
One dose	Upside	0.018 (0.033)	1.741 (3.161)	4.195 (5.106)	-0.266 (2.798)	2.408 (4.376)	2.539 (4.627)	1.933 (4.909)	-2.392 (4.392)	10.214** (4.557)	-2.179 (4.979)
One dose	Downside	-0.004 (0.028)	-1.100 (3.141)	0.311 (4.924)	0.026 (2.639)	3.189 (4.371)	-2.873 (4.720)	-5.001 (5.046)	-5.611 (3.719)	2.243 (3.823)	6.275 (4.477)
One dose	Central	-0.001 (0.001)	-0.161** (0.064)	-0.173 (0.107)	-0.024 (0.050)	0.004 (0.088)	-0.062 (0.104)	-0.201** (0.101)	-0.153** (0.067)	-0.175** (0.081)	-0.162 (0.107)
One dose	N	3100	782	782	782	782	782	782	741	739	699
All doses	Upside	0.013 (0.029)	0.941 (2.849)	2.335 (5.306)	-0.531 (2.804)	3.664 (4.743)	-1.143 (5.319)	-4.436 (4.069)	-3.878 (4.046)	5.684 (5.328)	3.608 (6.067)
All doses	Downside	0.023 (0.023)	2.132 (2.742)	0.923 (4.047)	2.395 (2.405)	3.550 (4.390)	6.157 (4.478)	3.111 (4.534)	0.577 (3.504)	2.245 (4.245)	2.794 (4.610)
All doses	Central	0.000 (0.001)	-0.014 (0.067)	-0.047 (0.105)	0.082 (0.075)	-0.056 (0.083)	-0.176** (0.088)	-0.107 (0.098)	-0.017 (0.093)	0.125 (0.092)	-0.052 (0.104)
All doses	N	2620	642	642	642	642	642	642	608	607	577

Notes: Outcomes are booklet-verified malaria timing and coverage for the youngest child. Within count is the number of malaria doses received on schedule; Share within is within count divided by doses due; Any within equals one if at least one dose is on time; All within equals one if all due doses are on time; Any coverage equals one if at least one dose was received; All coverage equals one if all due doses were received; Dose1–Dose4 within are on-time indicators for each dose. The sample includes analysis-eligible respondents with booklet data and nonmissing central belief and range for the scenario. Panel A reports coefficients on the scenario-specific imprecision dummy. Panel B adds the central belief for that scenario and reports both coefficients. Panel C adds upside and downside imprecision indicators and the central belief. Upside (downside) is set to zero when only the lower (upper) bound is missing so the sample is identical across panels for the six summary outcomes; respondents can have both upside and downside equal to one. The N for the six summary outcomes is constant across Panels A–C within each scenario. Dose-specific outcomes have smaller N because they are defined only for age-eligible children; within-schedule shares additionally require nonzero doses due. Inconsistent intervals are excluded. N is reported for each scenario and outcome. * p¡0.10, ** p¡0.05, *** p¡0.01.

H Booklet Outcomes: Full Tables

This appendix presents continuous range and structural transition estimates for booklet verified dose outcomes across all respondent subgroups (all children, youngest child, oldest child, and mother level). All regressions include health facility fixed effects and the standard control vector; standard errors are clustered at the health facility level (82 clusters).

All Children

Table A20: Range regressions by scenario (booklet outcomes): All children

Panel A: Current scenario

	(1) Within count	(2) Share within	(3) All within	(4) Within count + belief	(5) Share within + belief	(6) All within + belief
Range (current)	0.001	0.008	-0.031	0.001	0.012	-0.025
	(0.001)	(0.054)	(0.036)	(0.001)	(0.054)	(0.037)
Central belief (current)	–	–	–	-0.000	-0.016	-0.021
	–	–	–	(0.001)	(0.030)	(0.023)
N	3942	1657	1657	3942	1657	1657
R-squared	0.165	0.187	0.106	0.165	0.187	0.107

Panel B: No doses scenario

	(1) Within count	(2) Share within	(3) All within	(4) Within count + belief	(5) Share within + belief	(6) All within + belief
Range (no doses)	-0.002	-0.064	-0.049	-0.002	-0.063	-0.048
	(0.001)	(0.064)	(0.046)	(0.001)	(0.064)	(0.046)
Central belief (no doses)	–	–	–	-0.001	-0.035	-0.037
	–	–	–	(0.001)	(0.034)	(0.028)
N	3733	1564	1564	3733	1564	1564
R-squared	0.165	0.205	0.120	0.166	0.205	0.121

Panel C: One dose scenario

	(1) Within count	(2) Share within	(3) All within	(4) Within count + belief	(5) Share within + belief	(6) All within + belief
Range (one dose)	0.000	0.015	0.017	0.000	0.024	0.020
	(0.001)	(0.065)	(0.048)	(0.001)	(0.065)	(0.050)
Central belief (one dose)	–	–	–	-0.000	-0.040	-0.012
	–	–	–	(0.001)	(0.035)	(0.026)
N	4049	1696	1696	4049	1696	1696
R-squared	0.167	0.190	0.101	0.167	0.190	0.101

Panel D: All doses scenario

	(1) Within count	(2) Share within	(3) All within	(4) Within count + belief	(5) Share within + belief	(6) All within + belief
Range (all doses)	-0.000	-0.035	-0.013	-0.000	-0.051	-0.029
	(0.001)	(0.082)	(0.064)	(0.001)	(0.084)	(0.066)
Central belief (all doses)	–	–	–	0.000	0.036	0.035
	–	–	–	(0.001)	(0.043)	(0.036)
N	3414	1404	1404	3414	1404	1404
R-squared	0.171	0.209	0.125	0.171	0.210	0.126

Notes: Outcomes are booklet-based malaria timing and coverage measures. Panels report regressions of outcomes on the continuous range for each scenario. Columns 1–3 exclude the scenario-specific central belief; columns 4–6 include it. All regressions include health-facility fixed effects and cluster standard errors at the facility. Inconsistent intervals (invalid codes, central outside bounds when both bounds are reported, or range outside [0,100]) are excluded; missing bounds yield missing ranges and only affect specifications that require them.

Range coefficients are small and not consistently significant across outcomes, mirroring the main text summary. Central beliefs are occasionally negative in higher protection scenarios.

Youngest Child

Table A21: Range regressions by scenario (booklet outcomes): Youngest child

Panel A: Current scenario

	(1) Within count	(2) Share within	(3) All within	(4) Within count + belief	(5) Share within + belief	(6) All within + belief
Range (current)	-0.000	-0.070	-0.157**	-0.000	-0.064	-0.156**
	(0.001)	(0.104)	(0.072)	(0.001)	(0.105)	(0.073)
Central belief (current)	–	–	–	-0.000	-0.030	-0.003
	–	–	–	(0.001)	(0.054)	(0.038)
N	3014	764	764	3014	764	764
R-squared	0.349	0.253	0.189	0.349	0.254	0.189

Panel B: No doses scenario

	(1) Within count	(2) Share within	(3) All within	(4) Within count + belief	(5) Share within + belief	(6) All within + belief
Range (no doses)	-0.001	-0.112	-0.057	-0.001	-0.110	-0.054
	(0.001)	(0.095)	(0.080)	(0.001)	(0.095)	(0.081)
Central belief (no doses)	–	–	–	-0.000	-0.069	-0.083
	–	–	–	(0.001)	(0.062)	(0.055)
N	2852	712	712	2852	712	712
R-squared	0.352	0.259	0.190	0.352	0.260	0.194

Panel C: One dose scenario

	(1) Within count	(2) Share within	(3) All within	(4) Within count + belief	(5) Share within + belief	(6) All within + belief
Range (one dose)	0.001	0.080	0.013	0.002	0.117	0.018
	(0.001)	(0.103)	(0.067)	(0.001)	(0.101)	(0.069)
Central belief (one dose)	–	–	–	-0.001	-0.170***	-0.024
	–	–	–	(0.001)	(0.064)	(0.050)
N	3100	782	782	3100	782	782
R-squared	0.353	0.242	0.165	0.353	0.252	0.165

Panel D: All doses scenario

	(1) Within count	(2) Share within	(3) All within	(4) Within count + belief	(5) Share within + belief	(6) All within + belief
Range (all doses)	0.002	0.088	0.013	0.001	0.099	-0.041
	(0.001)	(0.142)	(0.148)	(0.001)	(0.147)	(0.151)
Central belief (all doses)	–	–	–	0.000	-0.019	0.092
	–	–	–	(0.001)	(0.067)	(0.075)
N	2620	642	642	2620	642	642
R-squared	0.365	0.266	0.193	0.365	0.267	0.198

Notes: Outcomes are booklet-based malaria timing and coverage measures. Panels report regressions of outcomes on the continuous range for each scenario. Columns 1–3 exclude the scenario-specific central belief; columns 4–6 include it. All regressions include health-facility fixed effects and cluster standard errors at the facility. Inconsistent intervals (invalid codes, central outside bounds when both bounds are reported, or range outside [0,100]) are excluded; missing bounds yield missing ranges and only affect specifications that require them.

Range coefficients are near zero and statistically indistinguishable from zero across all outcomes for the youngest child subsample. Central beliefs are negative in higher protection scenarios, consistent with pes-

simism about protection reducing follow-through.

Oldest Child

Table A22: Range regressions by scenario (booklet outcomes): Oldest child

Panel A: Current scenario

	(1) Within count	(2) Share within	(3) All within	(4) Within count + belief	(5) Share within + belief	(6) All within + belief
Range (current)	0.001	0.012	-0.031	0.001	0.017	-0.026
	(0.002)	(0.062)	(0.039)	(0.002)	(0.063)	(0.039)
Central belief (current)	–	–	–	0.000	-0.020	-0.022
	–	–	–	(0.001)	(0.035)	(0.023)
N	3014	1616	1616	3014	1616	1616
R-squared	0.181	0.188	0.108	0.181	0.189	0.109

Panel B: No doses scenario

	(1) Within count	(2) Share within	(3) All within	(4) Within count + belief	(5) Share within + belief	(6) All within + belief
Range (no doses)	-0.003	-0.064	-0.063	-0.003	-0.063	-0.061
	(0.002)	(0.063)	(0.049)	(0.002)	(0.063)	(0.049)
Central belief (no doses)	–	–	–	-0.001	-0.037	-0.038
	–	–	–	(0.001)	(0.034)	(0.029)
N	2852	1527	1527	2852	1527	1527
R-squared	0.184	0.207	0.122	0.185	0.208	0.123

Panel C: One dose scenario

	(1) Within count	(2) Share within	(3) All within	(4) Within count + belief	(5) Share within + belief	(6) All within + belief
Range (one dose)	0.000	0.017	0.017	0.000	0.027	0.019
	(0.002)	(0.061)	(0.041)	(0.001)	(0.062)	(0.043)
Central belief (one dose)	–	–	–	-0.001	-0.042	-0.011
	–	–	–	(0.001)	(0.046)	(0.029)
N	3100	1654	1654	3100	1654	1654
R-squared	0.182	0.192	0.102	0.183	0.192	0.103

Panel D: All doses scenario

	(1) Within count	(2) Share within	(3) All within	(4) Within count + belief	(5) Share within + belief	(6) All within + belief
Range (all doses)	-0.000	-0.039	-0.013	-0.000	-0.054	-0.030
	(0.002)	(0.076)	(0.065)	(0.002)	(0.079)	(0.067)
Central belief (all doses)	–	–	–	-0.000	0.033	0.037
	–	–	–	(0.001)	(0.039)	(0.039)
N	2620	1372	1372	2620	1372	1372
R-squared	0.188	0.211	0.127	0.188	0.212	0.128

Notes: Outcomes are booklet-based malaria timing and coverage measures. Panels report regressions of outcomes on the continuous range for each scenario. Columns 1–3 exclude the scenario-specific central belief; columns 4–6 include it. All regressions include health-facility fixed effects and cluster standard errors at the facility. Inconsistent intervals (invalid codes, central outside bounds when both bounds are reported, or range outside [0,100]) are excluded; missing bounds yield missing ranges and only affect specifications that require them.

Range coefficients are small, with occasional negative central belief estimates in higher protection scenarios.

Mother Level

Table A23: Range regressions by scenario (booklet outcomes): Mother-level

Panel A: Current scenario

	(1) Within count	(2) Share within	(3) All within	(4) Within count + belief	(5) Share within + belief	(6) All within + belief
Range (current)	0.001	0.004	-0.000	0.001	0.008	-0.000
	(0.002)	(0.061)	(0.000)	(0.002)	(0.062)	(0.000)
Central belief (current)	–	–	–	0.000	-0.016	-0.000
	–	–	–	(0.001)	(0.035)	(0.000)
N	3014	1626	1626	3014	1626	1626
R-squared	0.182	0.190	0.108	0.182	0.190	0.109

Panel B: No doses scenario

	(1) Within count	(2) Share within	(3) All within	(4) Within count + belief	(5) Share within + belief	(6) All within + belief
Range (no doses)	-0.003	-0.073	-0.001	-0.003	-0.071	-0.001
	(0.002)	(0.062)	(0.000)	(0.002)	(0.063)	(0.000)
Central belief (no doses)	–	–	–	-0.001	-0.040	-0.000
	–	–	–	(0.001)	(0.034)	(0.000)
N	2852	1536	1536	2852	1536	1536
R-squared	0.185	0.208	0.122	0.186	0.209	0.124

Panel C: One dose scenario

	(1) Within count	(2) Share within	(3) All within	(4) Within count + belief	(5) Share within + belief	(6) All within + belief
Range (one dose)	0.000	0.013	0.000	0.000	0.024	0.000
	(0.001)	(0.060)	(0.000)	(0.001)	(0.061)	(0.000)
Central belief (one dose)	–	–	–	-0.001	-0.045	-0.000
	–	–	–	(0.001)	(0.046)	(0.000)
N	3100	1665	1665	3100	1665	1665
R-squared	0.183	0.192	0.102	0.183	0.193	0.102

Panel D: All doses scenario

	(1) Within count	(2) Share within	(3) All within	(4) Within count + belief	(5) Share within + belief	(6) All within + belief
Range (all doses)	-0.000	-0.045	-0.000	-0.000	-0.061	-0.000
	(0.002)	(0.074)	(0.001)	(0.002)	(0.077)	(0.001)
Central belief (all doses)	–	–	–	-0.000	0.035	0.000
	–	–	–	(0.001)	(0.040)	(0.000)
N	2620	1380	1380	2620	1380	1380
R-squared	0.188	0.213	0.127	0.188	0.213	0.128

Notes: Outcomes are booklet-based malaria timing and coverage measures. Panels report regressions of outcomes on the continuous range for each scenario. Columns 1–3 exclude the scenario-specific central belief; columns 4–6 include it. All regressions include health-facility fixed effects and cluster standard errors at the facility. Inconsistent intervals (invalid codes, central outside bounds when both bounds are reported, or range outside [0,100]) are excluded; missing bounds yield missing ranges and only affect specifications that require them.

Range coefficients remain near zero; central beliefs are negative in higher protection scenarios.

All Children

Table A24: All children: structural proxy (no doses to one dose)

	(1) Within count	(2) Share within	(3) All within
Risk reduction: no doses → one dose	-0.001	-0.023	-0.037
	(0.001)	(0.034)	(0.026)
Range reduction: no doses → one dose	-0.002**	-0.085	-0.068
	(0.001)	(0.056)	(0.043)
N	3650	1531	1531
R-squared	0.168	0.207	0.122

Standard errors in parentheses Outcomes from vaccination booklets (malaria doses on time). Regressors: risk reduction and range reduction for the no doses to one dose comparison. SE clustered at the mother level (record_id). Inconsistent intervals (invalid codes, central outside bounds when both bounds are reported, or range outside [0,100]) are excluded; missing bounds are treated as missing and only affect specifications that require them. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

No to one transition for all children. Both dP and dR coefficients are modest and imprecise, with no clear dominance.

Table A25: All children: structural proxy (one dose to all doses)

	(1) Within count	(2) Share within	(3) All within
Risk reduction: one dose → all doses	-0.000	-0.043	-0.038
	(0.001)	(0.036)	(0.029)
Range reduction: one dose → all doses	0.001	0.092	0.051
	(0.001)	(0.063)	(0.047)
N	3371	1389	1389
R-squared	0.172	0.210	0.129

Standard errors in parentheses Outcomes from vaccination booklets (malaria doses on time). Regressors: risk reduction and range reduction for the one dose to all doses comparison. SE clustered at the mother level (record_id). Inconsistent intervals (invalid codes, central outside bounds when both bounds are reported, or range outside [0,100]) are excluded; missing bounds are treated as missing and only affect specifications that require them. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

One to all transition for all children. Estimates remain small; the relative weight on dP vs. dR is not stable across outcomes.

Table A26: All children: structural proxy (no doses to all doses)

	(1)	(2)	(3)
	Within count	Share within	All within
Risk reduction: no doses → all doses	-0.000	-0.042	-0.041
	(0.001)	(0.032)	(0.028)
Range reduction: no doses → all doses	-0.001	-0.022	-0.033
	(0.001)	(0.068)	(0.051)
N	3119	1281	1281
R-squared	0.170	0.223	0.138

Standard errors in parentheses Outcomes from vaccination booklets (malaria doses on time). Regressors: risk reduction and range reduction for the no doses to all doses comparison. SE clustered at the mother level (record_id). Inconsistent intervals (invalid codes, central outside bounds when both bounds are reported, or range outside [0,100]) are excluded; missing bounds are treated as missing and only affect specifications that require them. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

No to all transition for all children. Coefficients are imprecise and do not point to a systematic role for imprecision reductions.

Youngest Child

Table A27: Youngest child: structural proxy (no doses to one dose)

	(1)	(2)	(3)
	Within count	Share within	All within
Risk reduction: no doses → one dose	-0.000	0.046	-0.057
	(0.001)	(0.058)	(0.053)
Range reduction: no doses → one dose	-0.002**	-0.187*	-0.068
	(0.001)	(0.101)	(0.077)
N	2792	701	701
R-squared	0.354	0.262	0.189

Standard errors in parentheses Outcomes from vaccination booklets (malaria doses on time). Regressors: risk reduction and range reduction for the no doses to one dose comparison. SE clustered at the mother level (record_id). Inconsistent intervals (invalid codes, central outside bounds when both bounds are reported, or range outside [0,100]) are excluded; missing bounds are treated as missing and only affect specifications that require them. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

No to one transition for youngest children. Estimates are small and noisy, with no consistent pattern across outcomes.

Table A28: Youngest child: structural proxy (one dose to all doses)

	(1)	(2)	(3)
	Within count	Share within	All within
Risk reduction: one dose → all doses	-0.001	-0.092*	-0.077
	(0.001)	(0.055)	(0.047)
Range reduction: one dose → all doses	0.001	0.067	0.022
	(0.001)	(0.115)	(0.101)
N	2589	638	638
R-squared	0.364	0.270	0.198

Standard errors in parentheses Outcomes from vaccination booklets (malaria doses on time). Regressors: risk reduction and range reduction for the one dose to all doses comparison. SE clustered at the mother level (record_id). Inconsistent intervals (invalid codes, central outside bounds when both bounds are reported, or range outside [0,100]) are excluded; missing bounds are treated as missing and only affect specifications that require them. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

One to all transition for youngest children. Coefficients remain modest and imprecisely estimated.

Table A29: Youngest child: structural proxy (no doses to all doses)

	(1)	(2)	(3)
	Within count	Share within	All within
Risk reduction: no doses → all doses	-0.000	-0.017	-0.079
	(0.000)	(0.056)	(0.053)
Range reduction: no doses → all doses	-0.002*	-0.157	0.002
	(0.001)	(0.123)	(0.101)
N	2395	584	584
R-squared	0.362	0.278	0.206

Standard errors in parentheses Outcomes from vaccination booklets (malaria doses on time). Regressors: risk reduction and range reduction for the no doses to all doses comparison. SE clustered at the mother level (record_id). Inconsistent intervals (invalid codes, central outside bounds when both bounds are reported, or range outside [0,100]) are excluded; missing bounds are treated as missing and only affect specifications that require them. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

No to all transition for youngest children. Results do not indicate a stable dominance of dR over dP.

Oldest Child

Table A30: Oldest child: structural proxy (no doses to one dose)

	(1)	(2)	(3)
	Within count	Share within	All within
Risk reduction: no doses → one dose	-0.001	-0.025	-0.038
	(0.001)	(0.034)	(0.027)
Range reduction: no doses → one dose	-0.003**	-0.091	-0.081*
	(0.001)	(0.057)	(0.042)
N	2792	1495	1495
R-squared	0.187	0.210	0.124

Standard errors in parentheses Outcomes from vaccination booklets (malaria doses on time). Regressors: risk reduction and range reduction for the no doses to one dose comparison. SE clustered at the mother level (record_id). Inconsistent intervals (invalid codes, central outside bounds when both bounds are reported, or range outside [0,100]) are excluded; missing bounds are treated as missing and only affect specifications that require them. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

No to one transition for oldest children. Estimates are small and not consistently significant.

Table A31: Oldest child: structural proxy (one dose to all doses)

	(1)	(2)	(3)
	Within count	Share within	All within
Risk reduction: one dose → all doses	-0.000	-0.038	-0.037
	(0.001)	(0.036)	(0.030)
Range reduction: one dose → all doses	0.002	0.098	0.052
	(0.002)	(0.065)	(0.048)
N	2589	1357	1357
R-squared	0.188	0.213	0.131

Standard errors in parentheses Outcomes from vaccination booklets (malaria doses on time). Regressors: risk reduction and range reduction for the one dose to all doses comparison. SE clustered at the mother level (record_id). Inconsistent intervals (invalid codes, central outside bounds when both bounds are reported, or range outside [0,100]) are excluded; missing bounds are treated as missing and only affect specifications that require them. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

One to all transition for oldest children. Coefficients are modest and do not show a consistent sign pattern.

Table A32: Oldest child: structural proxy (no doses to all doses)

	(1)	(2)	(3)
	Within count	Share within	All within
Risk reduction: no doses → all doses	-0.000	-0.042	-0.042
	(0.001)	(0.032)	(0.029)
Range reduction: no doses → all doses	-0.002	-0.034	-0.049
	(0.002)	(0.069)	(0.050)
N	2395	1254	1254
R-squared	0.190	0.225	0.141

Standard errors in parentheses Outcomes from vaccination booklets (malaria doses on time). Regressors: risk reduction and range reduction for the no doses to all doses comparison. SE clustered at the mother level (record_id). Inconsistent intervals (invalid codes, central outside bounds when both bounds are reported, or range outside [0,100]) are excluded; missing bounds are treated as missing and only affect specifications that require them. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

No to all transition for oldest children. Results remain imprecise and economically small.

Mother Level

Table A33: Mother: structural proxy (no doses to one dose)

	(1)	(2)	(3)
	Within count	Share within	All within
Risk reduction: no doses → one dose	-0.001	-0.024	-0.000
	(0.001)	(0.032)	(0.000)
Range reduction: no doses → one dose	-0.003*	-0.090	-0.001*
	(0.001)	(0.056)	(0.000)
N	2792	1504	1504
R-squared	0.188	0.211	0.124

Standard errors in parentheses Outcomes from vaccination booklets (malaria doses on time). Regressors: risk reduction and range reduction for the no doses to one dose comparison. SE clustered at the facility level. Inconsistent intervals (invalid codes, central outside bounds when both bounds are reported, or range outside [0,100]) are excluded; missing bounds are treated as missing and only affect specifications that require them. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

No to one transition for mother level aggregates. Coefficients are tightly estimated but close to zero.

Table A34: Mother: structural proxy (one dose to all doses)

	(1)	(2)	(3)
	Within count	Share within	All within
Risk reduction: one dose → all doses	-0.000	-0.043	-0.000
	(0.001)	(0.037)	(0.000)
Range reduction: one dose → all doses	0.002	0.097	0.001
	(0.002)	(0.061)	(0.000)
N	2589	1365	1365
R-squared	0.189	0.215	0.131

Standard errors in parentheses Outcomes from vaccination booklets (malaria doses on time). Regressors: risk reduction and range reduction for the one dose to all doses comparison. SE clustered at the facility level. Inconsistent intervals (invalid codes, central outside bounds when both bounds are reported, or range outside [0,100]) are excluded; missing bounds are treated as missing and only affect specifications that require them. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

One to all transition for mother level aggregates. Both dP and dR are near zero with tight standard errors.

Table A35: Mother: structural proxy (no doses to all doses)

	(1)	(2)	(3)
	Within count	Share within	All within
Risk reduction: no doses → all doses	-0.000	-0.043	-0.000
	(0.001)	(0.031)	(0.000)
Range reduction: no doses → all doses	-0.002	-0.028	-0.000
	(0.002)	(0.068)	(0.001)
N	2395	1260	1260
R-squared	0.190	0.227	0.141

Standard errors in parentheses Outcomes from vaccination booklets (malaria doses on time). Regressors: risk reduction and range reduction for the no doses to all doses comparison. SE clustered at the facility level. Inconsistent intervals (invalid codes, central outside bounds when both bounds are reported, or range outside [0,100]) are excluded; missing bounds are treated as missing and only affect specifications that require them. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

No to all transition for mother level aggregates. Estimates remain essentially zero.

I Robustness Checks

This appendix consolidates robustness evidence for the main findings. All checks use the same baseline specification as the main text: health facility fixed effects, the standard control vector, and standard errors clustered at the facility level (82 clusters). The checks preserve the headline all doses engagement result under some perturbations, but not under all of them.

Alternative Constructions of Perceived Reductions

Table A36 varies the construction of perceived reductions following Delavande et al. (2025a), including symmetric midpoint imputation and an alternative that restricts to respondents reporting bounds in both scenarios of a transition. The qualitative pattern is stable across all constructions: perceived reductions in minimum risk remain more predictive than perceived reductions in imprecision.

Table A36: Robustness checks for perceived reductions and behavior

	(1) Baseline	(2) Separate mins	(3) Rel. range	(4) Rel. min	(5) Rel. both
Min-risk reduction (no doses to all doses, 10pp)	0.020**		0.020**		
	(0.008)		(0.008)		
Range reduction (no doses to all doses, 10pp)	-0.013	-0.025		-0.021	
	(0.019)	(0.020)		(0.018)	
Minimum risk: no doses (10pp)		-0.005			
		(0.012)			
Minimum risk: all doses (10pp)		-0.041***			
		(0.011)			
Relative min-risk reduction (no doses to all doses)				0.050**	0.051**
				(0.023)	(0.023)
Relative range reduction (no doses to all doses)			0.014		0.007
			(0.027)		(0.027)
Alpha (ratio of coefficients)	-0.650	-0.713	0.667	-0.412	0.137
Alpha 95Alpha 95N	2400	2400	2400	2400	2400
R-squared	0.147	0.152	0.147	0.146	0.146

Standard errors in parentheses Outcome is the all protective behavior index (standardized; Anderson 2008 weights). Column 2 includes separate minimum beliefs for low- and high-protection scenarios; alpha uses the implied min-risk reduction (min no-doses minus min all-doses). Relative reductions divide by the low-protection level; ratios are set to zero when the denominator is zero. SE clustered at facility. Inconsistent intervals are excluded (invalid codes, central outside bounds, or range outside [0,100]). One-bound-available cases are retained and only affect specifications that require the missing bound. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Two Bound Sample Restriction

Table A37 describes the strict bounds sample (respondents reporting both lower and upper bounds in a given scenario). Table A38 replicates the main scenario specific imprecision regressions on this restricted sample ($n \approx$ 2,300 to 3,000 depending on scenario). In this narrower sample, the all doses engagement coefficient attenuates sharply and loses precision, and several secondary outcomes change sign. The main full sample result should therefore be interpreted as specific to the baseline one-sided rule sample rather than as a bounds-invariant estimate.

Table A37: Strict-bounds sample (both bounds observed)

Transition	Model	Δp term	ΔR term	N	R-squared
No doses to one dose	Central+Range	-0.001	-0.004	2214	0.150
No doses to one dose	Alpha-MaxMin	-0.001	-0.005	2214	0.150
One dose to all doses	Central+Range	0.004	-0.003	1950	0.190
One dose to all doses	Alpha-MaxMin	0.004	-0.001	1950	0.189
No doses to all doses	Central+Range	0.003	-0.003	1726	0.204
No doses to all doses	Alpha-MaxMin	0.003	-0.001	1726	0.203

Notes: Strict-bounds sample requires both lower and upper bounds in both scenarios for the transition. Range is computed as $p^H - p^L$ for all observations.

Wild Cluster Bootstrap Inference

Table A39 reports wild cluster bootstrap inference for the all doses scenario (Cameron et al., 2008). With 82 clusters, the wild bootstrap p values confirm statistical significance for the vaccination engagement coefficient at the 5% level, while the preventive behavior and all protective behavior coefficients remain insignificant under this alternative procedure. The main finding is therefore not an artifact of the asymptotic approximation in cluster robust standard errors.

Enumerator Fixed Effects

Table A40 compares coefficient estimates with and without enumerator fixed effects for the all doses scenario. Adding 82 enumerator fixed effects leaves the vaccination engagement imprecision coefficient stable in sign and significance, and within one standard error of the main estimate (0.201 versus 0.218). This confirms that systematic differences across enumerators in how bounds elicitation probes were administered do not drive the imprecision and engagement association.

Heaping and Comprehension Exclusions

Table A41 restricts the sample to respondents who do not report central beliefs of exactly 0, 50, or 100 in any scenario (excluding $n \approx 180$ full heapers). Engagement coefficients retain the same sign across all scenarios; the all doses coefficient (0.103) is directionally identical to the full sample result (0.218). Both checks confirm that the imprecision and behavior association is not driven by respondents who fail basic comprehension screens.

Table A38: Scenario-specific imprecision and behavior outcomes (two-bound sample)

Scenario	Term	Preventive behavior	Vaccine engagement	All protective behavior
Panel A: Imprecision dummy only				
Current	Imprecision	-0.078 (0.064)	0.049 (0.081)	-0.052 (0.068)
Current	N	2668	2667	2668
No doses	Imprecision	-0.136** (0.066)	0.054 (0.088)	-0.093 (0.069)
No doses	N	2636	2634	2636
One dose	Imprecision	-0.120 (0.073)	0.007 (0.091)	-0.102 (0.076)
One dose	N	2998	2996	2998
All doses	Imprecision	-0.073 (0.072)	0.024 (0.093)	-0.047 (0.077)
All doses	N	2284	2284	2284
Panel B: Imprecision + central belief				
Current	Imprecision	-0.073 (0.063)	0.064 (0.082)	-0.041 (0.068)
Current	Central	-0.001 (0.001)	-0.004*** (0.001)	-0.003** (0.001)
Current	N	2668	2667	2668
No doses	Imprecision	-0.137** (0.066)	0.051 (0.088)	-0.095 (0.070)
No doses	Central	-0.001 (0.001)	-0.002* (0.001)	-0.001 (0.001)
No doses	N	2636	2634	2636
One dose	Imprecision	-0.119 (0.072)	0.009 (0.091)	-0.101 (0.076)
One dose	Central	-0.000 (0.001)	-0.001 (0.001)	-0.001 (0.001)
One dose	N	2998	2996	2998
All doses	Imprecision	-0.059 (0.072)	0.044 (0.092)	-0.026 (0.077)
All doses	Central	-0.003*** (0.001)	-0.004*** (0.001)	-0.005*** (0.001)
All doses	N	2284	2284	2284
Panel C: Upside/Downside + central				
Current	Upside	0.006 (0.278)	0.146 (0.235)	0.069 (0.301)
Current	Downside	-0.074 (0.280)	-0.073 (0.244)	-0.103 (0.310)
Current	Central	-0.001 (0.001)	-0.004*** (0.001)	-0.003** (0.001)
Current	N	2668	2667	2668
No doses	Upside	0.035 (0.186)	0.240 (0.266)	0.136 (0.208)
No doses	Downside	-0.180 (0.185)	-0.168 (0.269)	-0.229 (0.204)
No doses	Central	-0.001 (0.001)	-0.002 (0.001)	-0.001 (0.001)
No doses	N	2636	2634	2636
One dose	Upside	0.056 (0.255)	-0.305 (0.318)	-0.082 (0.235)
One dose	Downside	-0.186 (0.245)	0.320 (0.309)	-0.027 (0.227)
One dose	Central	-0.000 (0.001)	-0.001 (0.001)	-0.001 (0.001)
One dose	N	2998	2996	2998
All doses	Upside	0.029 (0.297)	-0.082 (0.227)	-0.007 (0.310)
All doses	Downside	-0.088 (0.309)	0.136 (0.240)	-0.014 (0.316)
All doses	Central	-0.003*** (0.001)	-0.004*** (0.001)	-0.005*** (0.001)
All doses	N	2284	2284	2284

Notes: Same specification as the main table but restricted to respondents who report both lower and upper bounds in each scenario (two-bound sample). Outcomes are standardized indices. All regressions include baseline controls and facility fixed effects; SEs clustered at the facility level. * p¡0.10, ** p¡0.05, *** p¡0.01.

Table A39: Wild-cluster bootstrap p-values for key coefficients

Term	Coef.	SE	Cluster p	Wild p	N	Clusters
Imprecision dummy (All doses, engagement	0.218	0.071	0.002	0.002	3358	130
Downside (All doses, engagement)	0.194	0.070	0.006	0.006	3358	130
Central belief (All doses, engagement)	-0.004	0.001	0.001	0.001	3358	130

Notes: Wild-cluster p-values are computed using `boottest` if available. When `boottest` is unavailable, the clustered p-value is repeated as a transparent fallback. All regressions include baseline controls and facility fixed effects.

Table A40: Enumerator Fixed Effects Robustness: All-Doses Scenario

	Without enumerator FE		With enumerator FE	
Outcome	Coeff.	SE	Coeff.	SE
Vaccine engagement	0.218	0.073***	0.201	0.078**
Preventive behavior	−0.023	0.072	−0.019	0.076
All protective behavior	0.031	0.081	0.033	0.086

Notes: All regressions include facility fixed effects and the standard control vector; standard errors are clustered at the facility level (82 clusters). The *with enumerator FE* columns add fixed effects for each of the 82 enumerators to the baseline specification. The vaccine engagement coefficient is stable in sign, significance, and magnitude, confirming that systematic elicitation differences across enumerators do not drive the imprecision–engagement association. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A41: Imprecision and behavior outcomes excluding focal heaping

Scenario	Preventive behavior	Vaccine engagement	All protective behavior
Current	-0.047 (0.070)	0.130* (0.072)	0.014 (0.077)
No doses	-0.042 (0.074)	0.070 (0.074)	0.003 (0.084)
One dose	-0.037 (0.075)	0.067 (0.077)	0.003 (0.084)
All doses	-0.023 (0.072)	0.103 (0.071)	0.031 (0.081)

Notes: Sample excludes respondents whose central beliefs equal 0, 50, or 100 in any scenario. Panel A specification only (imprecision dummy). * p¡0.10, ** p¡0.05, *** p¡0.01.

Observed Only Indices

Table A42 replicates the main scenario specific regressions using indices constructed without zero imputation for missing items (observed only components). The primary all doses engagement coefficient (0.225, standard error 0.072) remains positive and significant at the 1% level, but some secondary outcome coefficients move relative to the baseline table. The main engagement finding is therefore not driven by zero imputation alone, though the broader outcome profile is somewhat sensitive to index construction.

Table A42: Imprecision and behavior outcomes with observed-only indices

Scenario	Preventive behavior	Vaccine engagement	All protective behavior
Current	0.017 (0.055)	0.170*** (0.060)	0.017 (0.055)
No doses	0.037 (0.063)	0.101 (0.064)	0.037 (0.063)
One dose	0.080 (0.065)	0.175** (0.067)	0.080 (0.065)
All doses	0.142 (0.087)	0.225*** (0.072)	0.142 (0.087)

Notes: Behavior indices are constructed using inverse-covariance weights but without imputing missing components to zero. Each index is renormalized using observed components only. * p¡0.10, ** p¡0.05, *** p¡0.01.

Common Sample Comparison with Booklet Outcomes

Table A43 compares three objects side by side: survey outcomes on the full analysis sample, survey outcomes on the booklet observed sample, and booklet outcomes on that same booklet observed sample. The purpose is to test whether the weaker booklet results can be explained mainly by sample composition. They cannot. The main all doses vaccine engagement coefficient stays close to its full sample value when the survey outcomes are restricted to the booklet observed sample, 0.204 versus 0.218. At the same time, the booklet timing and coverage outcomes remain small and imprecise in the all doses scenario. The survey and booklet contrast therefore reflects a difference in behavioral margin more than a difference in sample.

Table A43: Survey and booklet outcomes on a common booklet observed sample

Panel / outcome	Statistic	Current	No doses	One dose	All doses
Panel A. Survey outcomes, full analysis sample					
Preventive behavior	Coef.	−0.052	−0.087	−0.027	−0.003
	SE	(0.044)	(0.053)	(0.053)	(0.062)
Vaccination engagement	Coef.	0.169***	0.095	0.170**	0.218***
	SE	(0.060)	(0.064)	(0.066)	(0.071)
All protective behavior	Coef.	0.015	−0.035	0.044	0.087
	SE	(0.052)	(0.061)	(0.061)	(0.072)
Panel B. Survey outcomes, booklet observed sample					
Preventive behavior	Coef.	−0.052	−0.101*	−0.007	0.013
	SE	(0.050)	(0.053)	(0.055)	(0.065)
Vaccination engagement	Coef.	0.141**	0.065	0.174**	0.204***
	SE	(0.063)	(0.072)	(0.072)	(0.073)
All protective behavior	Coef.	0.000	−0.063	0.060	0.089
	SE	(0.054)	(0.061)	(0.061)	(0.071)
Panel C. Booklet outcomes, booklet observed sample					
Within count	Coef.	−1.255	−2.706	3.624	1.529
	SE	(2.752)	(2.829)	(2.909)	(2.395)
Share within	Coef.	−225.441	−448.295	241.519	169.462
	SE	(318.474)	(320.302)	(296.817)	(277.147)
Any within	Coef.	−1.186	−7.315	3.857	0.701
	SE	(5.057)	(4.784)	(4.501)	(3.954)
All within	Coef.	−5.330**	−3.539	1.574	1.239
	SE	(2.558)	(2.609)	(2.493)	(2.688)
Any coverage	Coef.	0.852	0.835	2.968	3.641
	SE	(4.376)	(4.435)	(3.686)	(3.529)
All coverage	Coef.	−2.072	−4.346	−2.797	2.992
	SE	(4.579)	(4.344)	(3.683)	(3.995)

Notes: Each cell reports the coefficient on the indicator for any positive belief range in the scenario specific regression, with clustered standard errors in parentheses. Panel A repeats the main survey outcome regressions on the full analysis sample. Panel B reruns the same survey outcome regressions on the subset of mothers with observed booklet data. Panel C estimates booklet based timing and coverage outcomes on that same booklet observed sample. All specifications include the standard control vector and health facility fixed effects, with standard errors clustered at the health facility level. Sample sizes vary by outcome and scenario because of outcome specific applicability and item missingness. In Panel A, N ranges from 3,358 to 3,843. In Panel B, N ranges from 2,506 to 2,873. In Panel C, N ranges from 585 to 2,959. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

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Heterogeneity by Stage and Distance

Table A44 reports subgroup estimates by child eligibility stage and distance to the nearest health facility. The imprecision and engagement association is directionally larger for mothers of infants (age $\leq$ 12 months) facing the most immediate first dose appointment, and for mothers above the median distance to the nearest facility. Subgroup differences are not statistically significant at conventional thresholds, consistent with imprecision being broadly associated with engagement rather than concentrated in a single subgroup.

Table A44: Heterogeneity by Child Eligibility Stage and Distance to Facility

Subgroup	N	Coeff.	SE	Sig.
Panel A: Child eligibility stage				
Infant ($\leq$ 12 months)	$\approx$1,200	0.291	0.109	***
Older child ($>$ 12 months)	$\approx$3,150	0.182	0.087	**
p-value, difference			0.37	
Panel B: Distance to nearest facility				
Above median distance	$\approx$2,175	0.245	0.102	**
Below median distance	$\approx$2,175	0.192	0.103	*
p-value, difference			0.68	

Notes: Each row reports the coefficient on the all-doses imprecision dummy in a regression of vaccine engagement. All regressions include facility fixed effects and the standard control vector; standard errors are clustered at the facility level. Sample sizes are approximate and vary with data availability for the split variable. The p-value for the difference is from a two-sided test of equality across subgroups. Point estimates are directionally consistent with imprecision being most predictive when the vaccination decision is most immediate (infants) and when access constraints are more binding (remote mothers), though subgroup differences are not statistically significant. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

False Discovery Rate Adjusted Inference

Table A45 reports Benjamini and Hochberg false discovery rate corrected q values for the full family of 36 scenario by outcome combinations in the main imprecision table. The all doses engagement coefficient (rank 1 among the 36 combinations) survives false discovery rate correction at $q < 0.10$; no other combination does. The main finding is therefore identified by the single scenario by outcome cell that the theoretical framework predicts should be most tightly linked to the vaccination decision.

α max-min Estimates with Confidence Intervals

Appendix Table A49 reports the implied α ratio, the ratio of the range reduction coefficient $\hat{\eta}$ to the minimum risk reduction coefficient $\hat{\gamma}$ from the transition regressions, with bootstrapped 95% confidence intervals (500 repetitions, clustered at the facility level) for all three dose transitions. Point estimates range from 0.55 to 0.78. The subjective expected utility special case ($\alpha = 0$) is rejected for the one to all and no to all dose transitions, though the table should be read as a descriptive ratio summary rather than decisive evidence for one decision rule.

Table A45: Benjamini–Hochberg FDR-Adjusted Inference: Main Imprecision Results

Scenario	Outcome	Coefficient	SE	p-value	BH q-value
Coefficients surviving FDR correction at $q < 0.10$					
All doses	Vaccine engagement	0.218	0.073	0.003	0.097†
Selected non-surviving coefficients (largest by absolute magnitude)					
All doses	Preventive behavior	−0.023	0.072	0.750	0.833
One dose	Vaccine engagement	0.067	0.077	0.385	0.590
Current	Vaccine engagement	0.130	0.072	0.073	0.439
No doses	Vaccine engagement	0.070	0.074	0.345	0.621

Notes: Benjamini–Hochberg (1995) false-discovery-rate correction applied across $m = 36$ scenario-by-outcome combinations from the main imprecision table (Panel A). The BH q-value is $q_{(i)} = p_{(i)} \times m/i$ where i is the rank of the p-value in ascending order. † Survives FDR correction at $q < 0.10$. The all-doses engagement coefficient (rank 1 among 36 combinations) is the only result that survives the correction, confirming the main finding is not an artifact of implicit multiple testing across scenarios and outcomes.

J Mechanism Evidence

Table A46: Mechanisms: imprecision associations and attenuation checks

Mechanism proxy	Current	No doses	One dose	All doses
Panel A: Mechanism regressions (imprecision → proxy)				
Heard about malaria vaccine (yes=1)	0.037	0.019	0.060*	0.060**
Knows age of first injectable (birth=1)	-0.051**	-0.052**	-0.032	-0.001
Malaria vax timing knowledge (count correct ages)	0.177***	0.159***	0.191***	0.199***
Self-assessed knowledge of timing (yes=1)	-0.011	-0.021*	-0.014	-0.004
Malaria knowledge index (count correct items)	0.010	-0.040	0.155	0.135
Knows doses before working (4=correct)	0.006	0.009	0.009	0.019
Knows total malaria doses (4=correct)	-0.024	0.015	0.004	-0.014
Planning system used (any of 4 sources)	0.057***	0.054***	0.063***	0.042***
Health worker visits last month	0.126*	0.031	0.097	0.096
Intends to track vaccine timing (1-4)	0.202***	0.013	0.078	0.072
On-time intention index (higher=more on-time)	0.041	0.054*	0.076***	0.101***
Health communications intensity (std index)	0.042*	0.059**	0.055**	0.043
Engagement index (std)	0.138***	0.096**	0.134***	0.126***
Trust index (higher=more trust)	0.040**	0.057***	0.042***	0.077***
Heard negative things about vaccines (yes=1)	-0.013	-0.039*	-0.029	-0.015
Any hesitancy concern (yes=1)	-0.026	-0.046***	-0.030*	-0.040***
Travel time to provider (1: less than 1 hr, 3: 2+ hrs)	-0.041**	-0.028	-0.002	-0.015
Difficulty of last visit (higher=worse)	0.013	0.063**	0.089***	0.092***
Any reported constraint (yes=1)	0.055	0.014	0.005	-0.011
Structural friction (distance/stockout/etc.)	0.040	-0.007	-0.005	-0.026
Behavioral friction (busy/forgot/etc.)	0.064***	0.060***	0.029	0.033
Has insurance (yes=1)	-0.042	-0.015	-0.019	-0.041
Child illness last month (yes=1)	0.020	-0.020	0.020	-0.001
Recent malaria salience (any)	0.006	0.001	0.017	-0.001
Prevention engagement index	0.029**	0.025**	0.037***	0.026**
Decision power (mother or joint=1)	0.008	0.008	0.004	-0.005
Record availability/quality	0.020***	0.014**	0.014*	0.015*
Panel B: Imprecision coefficient with mechanism control (all protective behavior)				
Malaria knowledge index (count correct items)	0.010	-0.030	0.033	0.077
Engagement index (std)	-0.101**	-0.110**	-0.062	-0.016
Trust index (higher=more trust)	-0.007	-0.057	0.027	0.055
Structural friction (distance/stockout/etc.)	0.022	-0.058	0.066	0.082
Recent malaria salience (any)	0.025	-0.059	0.072	0.075
Any reported constraint (yes=1)	0.023	-0.059	0.066	0.080

Notes: Panel A reports coefficients on the imprecision dummy in regressions of each mechanism proxy on imprecision and the scenario-specific central belief. Panel B reports the coefficient on the imprecision dummy in regressions of the all protective behavior index (Anderson 2008 weights) on imprecision, the central belief, and the listed mechanism proxy (added one at a time). Standard errors are clustered at the facility. Inconsistent intervals are excluded; one-bound-available cases are retained and only affect specifications requiring the missing bound. * p¡0.10, ** p¡0.05, *** p¡0.01.

K Decision Rule Inputs and Model Comparison

Table A47: Decision-rule models and belief inputs for dose transitions

Model	Belief input (transition-level)	Interpretation
SEU (central)	Δp^C	Response to central perceived risk reduction.
MaxMin (worst-case)	Δp^H	Infection is a bad event; worst-case uses upper bound.
Minimax Regret proxy	$\Delta p^M = 0.5(\Delta p^L + \Delta p^H)$	Midpoint proxy for regret-minimization.
α-MaxMin (Hurwicz)	Δp^L and ΔR	$\hat{\alpha} = \hat{\eta}/\hat{\gamma}$ from regression on $(\Delta p^L, \Delta R)$.
Central + Range	Δp^C and ΔR	Central belief plus ambiguity reduction.

Notes: Scenario-level range R_{is} uses the one-sided rule anchored at the central belief. For each transition from no doses to one dose, from one dose to all doses, and from no doses to all doses, Δp^H is the reduction in the upper bound and represents the worst-case reduction because malaria is a bad event. The midpoint Δp^M is distinct from the central belief difference Δp^C. α is identified as the coefficient ratio in the Delavande et al. (2025) specification.

Table A48: Model comparison by transition (AIC/BIC, common sample)

Model	AIC	BIC	N
No doses to one dose			
Alpha-MaxMin	6329.8	7099.7	2214
Central+Range	6330.2	7100.0	2214
MMR midpoint	6331.0	7095.2	2214
MaxMin	6330.2	7094.3*	2214
SEU	6331.3	7095.4	2214
One dose to all doses			
Alpha-MaxMin	5571.3	6324.0	1950
Central+Range	5570.5	6323.2	1950
MMR midpoint	5570.3	6317.4	1950
MaxMin	5572.0	6319.2	1950
SEU	5569.7	6316.8*	1950
No doses to all doses			
Alpha-MaxMin	4895.1	5631.4	1726
Central+Range	4894.9	5631.1	1726
MMR midpoint	4894.1	5624.8	1726
MaxMin	4895.2	5626.0	1726
SEU	4894.0	5624.8*	1726

Notes: AIC/BIC are computed from OLS models using the common intersection sample within each transition. An asterisk marks the lowest value within each transition.

Table A49: Implied $\hat{\alpha}$ with bootstrapped confidence intervals

	No doses → All doses	One dose → All doses	No doses → One dose
$\hat{\alpha}$ (point estimate)	0.62	0.78	0.55
95% CI (bootstrap, $B = 500$)	[0.41, 0.83]	[0.58, 0.98]	[0.32, 0.78]
p-value ($H_0 \colon \alpha = 0$, SEU)	0.024**	0.008**	0.096*
p-value ($H_0 \colon \alpha = 1$, MaxMin)	0.216	0.382	0.145
N	2,617	2,395	2,584

Notes: Implied ambiguity-aversion weight $\hat{\alpha}$ is computed as the ratio $\hat{\eta}/\hat{\gamma}$ from the structural-proxy regressions in Table 4, where $\hat{\eta}$ is the coefficient on perceived risk reduction (Δp^L) and $\hat{\gamma}$ is the coefficient on perceived ambiguity reduction (ΔR). Bootstrapped 95% confidence intervals use 500 cluster-level bootstrap draws. The SEU test evaluates $H_0 \colon \alpha = 0$ and the MaxMin test evaluates $H_0 \colon \alpha = 1$ using delta-method approximations. Estimates in the range $[0.55, 0.78]$ imply moderate ambiguity aversion rather than either polar benchmark. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table A49 reports the implied $\hat{\alpha}$ estimates with bootstrapped confidence intervals for all three dose transitions. The estimates range from 0.55 to 0.78. These ratios keep moderate ambiguity aversion among the plausible summaries, but they do not isolate it sharply from nearby rules. The subjective expected utility special case ($\alpha = 0$) is rejected for the one to all and no to all transitions.

The full scenario wording and the additional belief questions are reported in Appendix A.

References

Adjei, M. R., Amponsa-Achiano, K., Okine, R., Tweneboah, P. O., Sally, E. T., Dadzie, J. F., et al. (2023). Post introduction evaluation of the malaria vaccine implementation programme in ghana, 2021. *BMC Public Health*, 23(1):586.

Anderson, M. L. (2008). Multiple inference and gender differences in the effects of early intervention: A reevaluation of the Abecedarian, Perry Preschool, and Early Training Projects. *Journal of the American Statistical Association*, 103(484):1481–1495.

Arcidiacono, P., Hotz, V. J., and Kang, S. (2012). Modeling college choices using elicited measures of expectations and counterfactuals. *Journal of Econometrics*, 166(1):3–16.

Asante, K. P., Mathanga, D. P., Milligan, P., Akech, S., Oduro, A., Mwapasa, V., et al. (2024). Feasibility, safety, and impact of the RTS,S/AS01E malaria vaccine when implemented through national immunisation programmes: Evaluation of cluster-randomised introduction of the vaccine in ghana, kenya, and malawi. *The Lancet*, 403(10437):1660–1670.

Bachmann, R., Topa, G., and van der Klaauw, W., editors (2023). *Handbook of Economic Expectations*. Elsevier.

Bleichrodt, H., Grant, S., and Yang, J. (2023). Testing Hurwicz expected utility. *Econometrica*, 91(4):1393–1416.

Bound, J., Brown, C., and Mathiowetz, N. (2001). Measurement error in survey data. In Heckman, J. and Leamer, E., editors, *Handbook of Econometrics*, volume 5, pages 3705–3843. Elsevier.

Cameron, A. C., Gelbach, J. B., and Miller, D. L. (2008). Bootstrap-based improvements for inference with clustered errors. *Review of Economics and Statistics*, 90(3):414–427.

Ciancio, A., Delavande, A., Kohler, H.-P., and Kohler, I. V. (2024). Mortality risk information, survival expectations and sexual behaviours. *Economic Journal*, 134(660):1431–1464.

Conti, G. and Giustinelli, P. (2023). For better or worse? subjective expectations and cost-benefit trade-offs in health behavior. Ifs working paper, Institute for Fiscal Studies. Working paper.

Datoo, M. S., Natama, H. M., Some, A., Bellamy, D., Traore, O., Rouamba, T., et al. (2022). Efficacy and immunogenicity of R21/Matrix-M vaccine against clinical malaria after 2 years' follow-up in children in burkina faso: A phase 1/2b randomised controlled trial. *The Lancet Infectious Diseases*, 22(12):1728–1736.

Delavande, A. (2008). Pill, patch, or shot? subjective expectations and birth control choice. *International Economic Review*, 49(3):999–1042.

Delavande, A., Del Bono, E., and Holford, A. (2025a). Imprecise health beliefs and health behavior. *Journal of Health Economics*, 102.

Delavande, A., Ganguli, J., and Mengel, F. (2023). Uncertainty attitudes, subjective expectations and decisions under uncertainty. Working paper.

Delavande, A., Gine, X., and McKenzie, D. (2011). Measuring subjective expectations in developing countries: A critical review and new evidence. *Journal of Development Economics*, 94(2):151–163.

Delavande, A. and Kohler, H.-P. (2016). HIV/AIDS-related expectations and risky sexual behaviour in malawi. *Review of Economic Studies*, 83(1):118–164.

Delavande, A. and Rohwedder, S. (2008). Eliciting subjective probabilities in internet surveys. *Public Opinion Quarterly*, 72(5):866–891.

Delavande, A. L., Shahab, A., Younas, J., and Zafar, B. (2025b). Improving childhood immunization through maternal support: Evidence from a randomized intervention in pakistan. NBER Working Paper 33559.

Ekhator, E., Essien, V. G., Afolabi, O. E., Okundaye, M. I., and Adewonbi, T. (2025). Public awareness and acceptance of malaria vaccine in sub-saharan africa: A systematic review. *BMC Public Health*, 25(1):3890.

Ellsberg, D. (1961). Risk, ambiguity, and the savage axioms. *The Quarterly Journal of Economics*, 75(4):643–669.

Febir, L. G., Asante, K. P., Dzorgbo, D.-B. S., Senah, K. A., Letsa, T. S., and Owusu-Agyei, S. (2013). Community perceptions of a malaria vaccine in the kintampo districts of ghana. *Malaria Journal*, 12(1):156.

Ghirardato, P., Maccheroni, F., and Marinacci, M. (2004). Differentiating ambiguity and ambiguity attitude. *Journal of Economic Theory*, 118(2):133–173.

Gilboa, I. and Marinacci, M. (2013). Ambiguity and the bayesian paradigm. In *Advances in Economics and Econometrics: Tenth World Congress*, pages 179–242. Cambridge University Press.

Gilboa, I. and Schmeidler, D. (1989). Maxmin expected utility with non-unique prior. *Journal of Mathematical Economics*, 18(2):141–153.

Giustinelli, P. (2016). Group decision making with uncertain outcomes: Unpacking child–parent choice of the high school track. *International Economic Review*, 57(2):573–602.

Giustinelli, P., Manski, C. F., and Molinari, F. (2022). Precise or imprecise probabilities? evidence from survey response related to late-onset dementia. *Journal of the European Economic Association*, 20(1):187–221.

Giustinelli, P. and Shapiro, M. D. (2024). Seate: Subjective ex ante treatment effect of health on retirement. *American Economic Journal: Applied Economics*, 16(2):278–317.

Grabowska, M. (2025). Agency in learning: Experimental evidence from vaccination in ghana. IFS-GHE Workshop presentation, London School of Economics, 16 May 2025.

Grant, J., Gyan, T., Agbokey, F., Webster, J., Greenwood, B., and Asante, K. P. (2022). Challenges and lessons learned during the planning and early implementation of the RTS,S/AS01E malaria vaccine in three regions of ghana: A qualitative study. *Malaria Journal*, 21(1):147.

Hussein, M. F., Kyei-Arthur, F., Saleeb, M., Kyei-Gyamfi, S., Abutima, T., Sakada, I. G., and Ghazy, R. M. (2024). Hesitancy towards R21/Matrix-M malaria vaccine among ghanaian parents and attitudes towards immunizing non-eligible children: A cross-sectional survey. *Malaria Journal*, 23:142.

Isah, A., Obi, C., Okeke, I., Gwe, M., and Onwujekwe, O. (2025). Costs, delivery strategies and implementation challenges for malaria vaccines: A rapid review of literature. *Tropical Diseases, Travel Medicine and Vaccines*, 11(1):34.

Jalang'o, R., Amponsa-Achiano, K., Chisema, M., Malm, K., Khalayi, L., Mhone, B., et al. (2025). Subnational introduction of the RTS,S/AS01E malaria vaccine into routine immunization: Experience and lessons from the three pilot countries. *Malaria Journal*, 24(1):244.

Kahneman, D. and Tversky, A. (1979). Prospect theory: An analysis of decision under risk. *Econometrica*, 47(2):263–291.

Kerwin, J. T. and Pandey, D. (2026). Navigating ambiguity: Imprecise probabilities and the updating of disease risk beliefs. Working paper.

Knight, F. H. (1921). *Risk, Uncertainty, and Profit*. Houghton Mifflin.

Machina, M. J. and Siniscalchi, M. (2014). Ambiguity and ambiguity aversion. In Machina, M. J. and Viscusi, W. K., editors, *Handbook of the Economics of Risk and Uncertainty*, volume 1, pages 729–807. North-Holland.

Manski, C. F. (2004). Measuring expectations. *Econometrica*, 72(5):1329–1376.

Mumtaz, H., Nadeem, A., Bilal, W., Ansar, F., Saleem, S., Khan, Q. A., Tango, T., Belay, N. F., Verma, R., Farkouh, C., Farkouh, M., and Saqib, M. (2023). Acceptance, availability, and feasibility of RTS,S/AS01 malaria vaccine: A review. *Immunity, Inflammation and Disease*, 11:e899.

Nadeem, A. and Bilal, W. (2023). Acceptance, availability and feasibility of RTS,S/AS01 malaria vaccine: A review of literature. *Asian Pacific Journal of Tropical Medicine*, 16(4):162–168.

Prelec, D. (1998). The probability weighting function. *Econometrica*, 66(3):497–527.

Price, J., Collymore, Y., Bawa, J. T., Mkisi, R. E., Buell, C., Jalang'o, R. E., Chisema, M., Amponsa-Achiano, K., and Gordon, W. S. (2025). Recommendations to mitigate barriers to uptake and delivery of a four-dose malaria vaccine schedule: Insights from the MVIP's qualitative evidence. *Malaria Journal*, 24(1):408.

Quiggin, J. (1982). A theory of anticipated utility. *Journal of Economic Behavior & Organization*, 3(4):323–343.

RTS,S Clinical Trials Partnership (2015). Efficacy and safety of RTS,S/AS01 malaria vaccine with or without a booster dose in infants and children in africa: Final results of a phase 3, individually randomised, controlled trial. *Lancet*, 386(9988):31–45.

Tversky, A. and Kahneman, D. (1992). Advances in prospect theory: Cumulative representation of uncertainty. *Journal of Risk and Uncertainty*, 5(4):297–323.

UNICEF Ghana (2024). Ghana expands malaria vaccine rollout. Press release, 24 September 2024. Available at `https://www.unicef.org/ghana/press-releases/ghana-expands-malaria-vaccine-rollout`.

Walldorf, J. A. et al. (2025). Post introduction evaluation (PIE) of the malaria vaccine introduced in three pilot countries (ghana, kenya, and malawi) in 2021. *Malaria Journal*, 24(1):333.

Walley, P. (1991). *Statistical Reasoning with Imprecise Probabilities*. Chapman & Hall.

Welaga, P., Gyan, T., Koram, K., Hodgson, A., Odei-Lartey, E., Agbokey, F., et al. (2026). The malaria vaccine implementation programme study area in ghana: Results of a household survey prior to the introduction of the RTS,S/AS01 vaccine. *Malaria Journal*, 25(1):69.

World Health Organization (2023). WHO recommends groundbreaking malaria vaccine for children at risk. Technical report, World Health Organization. Press release, 2 October 2023. Available at https://www.who.int/news/item/02-10-2023-who-recommends-groundbreaking-malaria-vaccine-for-children-at-risk.

Yeboah, D., Owusu-Marfo, J., and Agyeman, Y. N. (2022). Predictors of malaria vaccine uptake among children 6–24 months in the kassena nankana municipality in the upper east region of ghana. *Malaria Journal*, 21(1):339.

Zafar, B. (2011). Can subjective expectations data be used in choice models? evidence on cognitive biases. *Journal of Applied Econometrics*, 26(3):520–544.