

BEHAVIORAL AND EXPERIMENTAL ECONOMICS RESEARCH LAB

Planning frictions and the incomplete take-up of health investments: The case of HPV vaccination

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August 2026



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This version: August 14, 2026

Abstract

Failure to complete vaccination schedules represents an important form of health underinvestment in developing economies. We study this problem in the context of HPV vaccination in Colombia, where many girls initiate but do not complete the schedule. Messages framing a vaccine as reserved for the recipient can increase uptake, but they may be less effective when the relevant barrier is planning rather than entitlement. We test this hypothesis in a randomized controlled trial with parents of girls located inside and outside Bogotá who had initiated but not completed HPV vaccination. The experiment compares ownership reminders with time-specific planning prompts: messages suggesting a specific day and time for vaccination without assigning an appointment or changing the formal choice set. The planning-prompt treatment and the combined treatments increase second-dose completion by 7.94 to 9.10 percentage points, relative to 8.63 percent in the control group, while the ownership reminder increases completion by 4.58 percentage points. This ranking is consistent with planning and implementation frictions being more binding than entitlement frictions among marginal households, although the experiment does not directly measure these mechanisms.

Keywords: Planning prompts; ownership reminders; health investments.

JEL Classification Numbers: I14, O15, C93.

*We thank the American Cancer Society for funding this project. We are grateful to Claudia Acosta, Patricia Calderón, and José Garzón from the Secretaría de Salud de Bogotá; Marta Marín from the Ministerio de Salud de Colombia; Carlos Castro, Karen Salinas, Mónica Giraldo, and Laura Gil from the Liga Colombiana contra el Cáncer; Meenu Anand, Erika Rees-Punia, and Itziar Belasteuguigoitia from the American Cancer Society; and Carlos Scartascini from the Inter-American Development Bank for their support during the design and implementation of the experiment. We also benefited from comments and suggestions by Sebastian Gallegos, Paul Rodriguez, Nicolas Ajzenman, and Kristian Lopez, as well as participants at the LACEA-BRAIN Workshop in Barbados and seminars at Universidad del Rosario. The study received IRB approval from Universidad del Rosario (DVO005 1663-CV1287) and was registered in the AEA RCT Registry (AEARCTR-0009705).

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1 Introduction

Many valuable health investments in developing countries require more than initial adoption. Individuals may begin preventive treatment without returning for a follow-up visit, or receive a first vaccine dose without completing the schedule.¹ Initial take-up reveals that individuals attach some value to the investment, making noncompletion difficult to explain by lack of demand alone. Noncompletion may instead reflect the need to remember, plan, and act after a delay (Ajzen, 1991; Gollwitzer, 1999). We study whether helping individuals translate an intention to invest into concrete action reduces these completion failures in the context of vaccination (Webb and Sheeran, 2006; Gollwitzer and Sheeran, 2006).

Vaccination provides a useful setting to study this problem. Vaccines generate large private and social returns and have prevented millions of deaths in low- and middle-income countries (Li et al., 2021).² Yet incomplete schedules remain common. The literature extensively examines reasons for non-vaccination, including beliefs about safety, adverse events, disease severity, and disease risk (Azarpanah et al., 2021; Brewer et al., 2007), but less is known about increasing completion after initiation. Completion differs from initial adoption: parents who start a schedule may still fail to complete it because of procrastination, limited prospective memory, overconfidence in memory capacity, or the cognitive costs of translating intentions into concrete action (Nuscheler and Roeder, 2016; McDaniel and Einstein, 2007; Ericson, 2011; Tasoff and Letzler, 2014). Incomplete vaccination thus exemplifies the intention-action gap.³

This margin may be particularly consequential in developing economies, where poverty

¹These investments require follow-through after initiation: childhood vaccination schedules involve repeated visits (Banerjee et al., 2010), while tuberculosis treatment requires sustained adherence (Alipanah et al., 2018).

²Li et al. (2021) estimate that vaccination against ten pathogens in 98 low- and middle-income countries prevented 37 million deaths in 2000–2019 and could avert 32 million more by 2030.

³Reviews of the intention–behavior gap show that intentions imperfectly predict subsequent behavior and that interventions that increase intentions often produce smaller behavioral changes (Webb and Sheeran, 2006). Research on implementation intentions shows that specifying when, where, and how to act can help translate intentions into behavior (Gollwitzer and Sheeran, 2006), including preventive health behaviors such as influenza vaccination (Milkman et al., 2011).

compounds cognitive demands with larger material and institutional costs. Scarcity can divert attention from future tasks toward urgent needs (Shah et al., 2012).⁴ Poor households also face frequent consequential decisions with fewer tools to automate or simplify routine actions (Bertrand et al., 2006; Schilbach et al., 2016). Consistent with these constraints, full childhood immunization is concentrated among wealthier households in 46 low- and middle-income countries (Hajizadeh, 2018).

A growing literature shows that light-touch reminders can reduce noncompletion when individuals intend to act but fail to follow through. In vaccination, Milkman et al. (2021) and Dai et al. (2021) show that messages suggesting a vaccine has been reserved for the recipient can increase uptake. Beyond providing information, these ownership reminders may create a sense of entitlement over the vaccine, making non-vaccination feel like failing to claim something already assigned. Consistent with a large literature in behavioral economics on reference dependence and loss aversion (Kahneman and Tversky, 1979; O’Donoghue and Sprenger, 2018), they can shift the reference point from whether to obtain the vaccine to whether to give up a reserved opportunity.⁵

However, ownership reminders may leave an implementation problem unresolved: a parent told that a vaccine is reserved for her daughter must still decide when to go, coordinate the visit, and act. This matters when noncompletion reflects difficulty translating general intentions into concrete plans more than opposition to vaccination. A planning prompt instead makes a specific course of action focal without changing the formal choice set. In our setting, this message suggests a specific vaccination day and time without assigning an appointment, restricting alternatives, or changing what happens under inaction. Their

⁴In complementary field evidence, Mani et al. (2013) find that financial concerns reduce cognitive performance among low-income but not affluent participants; the same Indian farmers perform worse before than after harvest.

⁵This interpretation follows Milkman et al. (2021), whose best-performing flu-vaccination text reminders used “reserved for you” language, and Buitendijk et al. (2022), who describe this framing as combining default expectations, reciprocity, and psychological ownership. In COVID-19 vaccination, Dai et al. (2021) use “claim your dose” to induce psychological ownership, while Patel et al. (2022) interpret reservation messages through loss aversion.

relative effectiveness in increasing completion is therefore an empirical question with direct implications for designing follow-through interventions.

We study this question in a randomized controlled trial among parents of girls in and outside Bogotá, Colombia, who had received the first dose of the human papillomavirus (HPV) vaccine but not completed the schedule. HPV vaccination is an important preventive health investment because HPV is causally associated with cervical cancer. Colombia offers a relevant setting: initially high coverage under the national campaign fell sharply after a widely publicized health episode in Carmen de Bolívar, linked to the vaccine in public debate (Martínez et al., 2015). HPV vaccination consequently became a contested investment, while completion remained low.⁶ Focusing on parents of first-dose recipients allows us to study completion among households that had revealed some willingness to vaccinate.

Parents were randomly assigned to six mutually exclusive conditions: pure control, placebo message, ownership reminder, planning prompt, and two treatments combining the planning prompt with an ownership reminder 24 or two hours before the suggested vaccination time. The pure control identifies each complete communication package’s effect relative to no SMS; the placebo tests whether contact from the health authority on an unrelated health topic changes HPV completion. The ownership and planning arms most directly compare the two behavioral approaches. Comparing planning alone with the combined packages tests gains from adding ownership language; comparing the combined arms isolates whether reminder timing matters.

These contrasts motivate a simple conceptual framework: a parent completes the schedule when its perceived net value outweighs transportation, time, hassle, and planning costs. Messages may affect this decision by changing salient reference points. An ownership reminder may create an entitlement reference point, making noncompletion feel like failing to claim something assigned to the daughter. A planning prompt may instead create a plan

⁶First-dose coverage fell from 97.5 percent in 2013 (Nogueira-Rodrigues, 2019) to 14 percent in 2016, when second-dose coverage was 9 percent (Simas et al., 2019). Online Appendix Figure A-1 presents the national series through 2022.

reference point, making a specific day and time focal and reducing the cognitive cost of deciding when to act. Their relative effectiveness is theoretically ambiguous. Combining them need not yield additive effects if they operate on overlapping margins, the suggested time is inconvenient, or additional messages create burden or confusion.

The experiment’s scale and administrative records let us evaluate realized vaccination rather than stated intentions. The study includes 5,907 randomized parent records, each linked to one eligible daughter. Vaccination providers report completed doses to Bogota’s administrative vaccination registry (PAIWEB), allowing us to observe second-dose completion for the full randomized sample and exact vaccination dates for dynamic analysis. This avoids conventional survey attrition and lets us examine whether effects emerge during the campaign and persist after message delivery. We registered the experiment and its pre-analysis plan before requesting or analyzing final outcome data.⁷

Arm-specific estimates show that both approaches increase completion, with larger effects from planning prompts. Relative to a pure-control completion rate of 8.63 percent, ownership reminders and planning prompts increase second-dose completion by 4.58 and 8.67 percentage points, respectively; a direct test rejects equality. The combined treatments increase completion by 7.94 points with ownership reminders 24 hours before the suggested time and 9.10 points with reminders two hours before. These effects are statistically indistinguishable from the effect of planning alone, indicating no detectable gain from adding ownership language.⁸

These results remain stable across alternative specifications, comparison groups, multiple-

⁷The experiment is registered with the AEA registry (AEARCTR-0009705). The pre-analysis plan is reproduced in Online Appendix B.

⁸Ownership and planning raise completion by about 53 and 100 percent over our pure-control mean. In U.S. influenza vaccination, Milkman et al. (2011) find a 4.2-percentage-point gain from date-and-time planning prompts over a standard reminder mailing; the best reservation messages yield 4.6 and 2.9 points in primary-care and pharmacy megastudies, respectively (Milkman et al., 2021, 2022). In Guatemala, Busso et al. (2015) report age-appropriate vaccination completion gains of 2.2 points overall and 4.6 among children due for vaccination. In a Bogotá experiment, Maldonado et al. (2026) find that dynamic social norms increase first-dose HPV vaccination by about 1.28 points, or 23 percent. Our planning estimate is large by these benchmarks; the ownership estimate is close to the larger reminder effects. Vaccines, baseline rates, follow-up periods, and control conditions differ; we study second-dose completion among families that had already initiated vaccination.

testing corrections, and randomization inference. Treatment-control gaps persist after message delivery, indicating increased cumulative completion rather than merely shifting vaccination to the suggested date. Larger effects among younger girls and families inside Bogotá were not accompanied by pre-specified directional hypotheses. Planning costs an estimated USD 0.38 per additional completion, compared with USD 0.72 for ownership.⁹ These results are consistent with planning and implementation frictions being more binding than entitlement frictions among marginal parents, although the experiment does not directly measure the underlying psychological processes.

We make three contributions. First, we contribute to the growing literature applying behavioral insights to vaccination decisions (Betsch et al., 2015; Brewer et al., 2017). Studies have increased vaccination through more reliable access and incentives (Banerjee et al., 2010), reminders (Milkman et al., 2021, 2022), and implementation-intention prompts (Milkman et al., 2011). Although some examine full immunization schedules (Banerjee et al., 2010; Gibson et al., 2017), much evidence concerns whether eligible individuals receive a vaccine. We instead study whether parents whose daughters had received a first HPV dose complete the schedule after a delay. Initial vaccination reveals some willingness to invest, allowing us to focus on follow-through after adoption. We thus extend the behavioral-vaccination literature from initial take-up to completion, a central margin in multi-stage health investments and especially relevant when intentions must be remembered, planned, and executed over time (Webb and Sheeran, 2006; Gollwitzer and Sheeran, 2006).

Second, we connect two literatures developed largely in parallel. Research on implementation intentions and planning prompts shows that linking goals to concrete future occasions

⁹In a social-norm experiment, Maldonado et al. (2026) report USD 5.53 per additional first HPV dose and USD 3.93 for the more effective norm designs; our planning estimate is about one tenth of the latter. Other studies report USD 7.50 per additional child completing age-appropriate vaccination in Guatemala (Busso et al., 2015) and USD 7.90 per additional return visit for childhood vaccination in Nigeria (Kawakatsu et al., 2020). For social-media campaigns, Athey et al. (2023) estimate USD 5.68 per additional COVID-19 vaccination by linking experimental belief changes to observational vaccination rates. These comparisons use reported prices and differ in outcomes, cost coverage, and price years. Our ratios cover direct SMS and personnel costs within existing infrastructure, excluding vaccine provision and household costs, rather than full social costs per additional vaccination.

can improve follow-through (Gollwitzer, 1999; Gollwitzer and Sheeran, 2006; Milkman et al., 2011; Rogers et al., 2015). Complementary evidence shows that reservation language can increase vaccination by making a dose feel allocated to the recipient (Milkman et al., 2021, 2022; Dai et al., 2021; Buttenheim et al., 2022; Patel et al., 2022). Both approaches can be effective, but evidence comparing them within the same experiment, population, and outcome is limited. Beyond testing another reminder, we compare two leading behavioral approaches to completion and assess whether their effects are additive.

Third, we contribute to experimental research on digital vaccination outreach through public systems. Text messages and reminder letters can increase HPV vaccination and completion of multi-dose schedules (Rand et al., 2017; Tull et al., 2019; Chao et al., 2015). Embedding the intervention in a local health authority’s existing infrastructure also connects the study to large-scale field experimentation and behavioral interventions in public administration (Banerjee et al., 2025; Muralidharan and Niehaus, 2017; Benartzi et al., 2017). Cost-effectiveness estimates translate these effects into direct implementation costs. These features show how administrative data and low-cost messaging can support comparison and refinement of behavioral designs within an operational vaccination system, beyond sending reminders.

The rest of the paper is organized as follows. Sections 2–5 present the conceptual framework, institutional background, research design, and empirical model, respectively. Section 6 reports the main results, including dynamic effects, treatment-effect heterogeneity, and robustness to multiple-inference adjustments. Section 7 presents the cost-effectiveness analysis, and Section 8 concludes.

2 Conceptual framework

We use a simple framework to compare ownership reminders and planning prompts. The framework draws on models of reference-dependent preferences (Kőszegi and Rabin, 2006), limited attention and reminders (Karlan et al., 2016), and self-regulation through goal

setting (Koch and Nafziger, 2011). We adapt these elements to the decision to complete the HPV vaccination schedule and clarify why the relative effectiveness of the two messages is theoretically ambiguous.

In our framework, a parent decides whether to complete her daughter’s HPV vaccination schedule. Let $x_i \in \{0, 1\}$ denote completion, where $x_i = 1$ if the daughter receives the second dose and $x_i = 0$ otherwise. The net value of completion before accounting for reference-dependent utility or message effects is $\theta_i = B_i - C_i$, where B_i is the parent’s perceived value of completing the HPV schedule and C_i is the full cost of taking the daughter to be vaccinated. This cost includes transportation and time costs, but also hassle costs, uncertainty about when to go, and the cognitive cost of converting a general intention into a concrete action.¹⁰ In a benchmark without reference-dependent utility or message effects, the parent completes the schedule whenever $\theta_i \geq 0$.

The interventions may affect completion by changing the way parents evaluate action and inaction. An ownership reminder can create an entitlement reference point: the parent may perceive the vaccine as something assigned to her daughter and may evaluate noncompletion as failing to claim a reserved good.¹¹ A planning-prompt message can create a plan reference point: a specific day and time becomes the focal or expected moment for vaccination.¹² This message does not create an administrative default because no appointment is formally scheduled, parents remain free to vaccinate at another time, and inaction still results in

¹⁰Models of task completion distinguish the costs of carrying out an activity from its subsequent rewards (O’Donoghue and Rabin, 1999). Reis (2006) explicitly models the resource costs of acquiring and processing information and determining a plan of action. These contributions motivate treating the cost of vaccination as broader than its monetary price.

¹¹Reference-dependent models allow a change in the reference point to alter the valuation of otherwise unchanged outcomes (Tversky and Kahneman, 1991). In expectations-based formulations, failing to obtain an anticipated good can be experienced as a loss even if the good was not previously owned (Kőszegi and Rabin, 2006). In our setting, this interpretation requires the parent to adopt the perceived allocation as a reference point; it does not require a physical transfer of the dose or a change in her vaccination options.

¹²Koch and Nafziger (2011) model goals as reference points that motivate effort by making shortfalls psychologically costly. Their model concerns goals chosen by an individual facing self-control problems. We draw on the reference-point role of goals to interpret the suggested vaccination time: if the parent adopts the proposed plan as a benchmark, failing to complete the schedule may carry a psychological cost in addition to the forgone health benefit.

non-vaccination. Instead, it makes one course of action psychologically salient.

Formally, let t denote the experimental condition. The treatment can affect five objects. First, $s_i(t)$ captures the salience effect of receiving a message from the health authority, including institutional contact, personalization, and attention drawn to the vaccination decision. We allow $s_i(t)$ to vary across message conditions; equal salience is an additional assumption used in the propositions.¹³ Second, ownership language may strengthen the entitlement reference point, $e(t)$, which indexes the extent to which the dose is perceived as assigned to the daughter. Third, the suggested day and time may strengthen the plan reference point, $p(t)$, which indexes the extent to which that time serves as a benchmark for action.¹⁴

The remaining two objects capture costs associated with acting and with the message itself. A planning-prompt message may reduce planning and implementation costs, but an inconvenient suggested time may also create mismatch costs if it disrupts an alternative plan.¹⁵ Let $\omega_i a(t)$ denote this net implementation effect, where $a(t) = 1$ for treatments that include a suggested day and time and $a(t) = 0$ otherwise. The parameter ω_i can be positive, zero, or negative. Finally, let $\kappa_i(t) \geq 0$ denote an additional cost of completing the schedule generated by confusion, fatigue, or complexity from combining messages. We set this term to zero outside the combined treatments as a simplifying restriction.¹⁶

¹³Karlan et al. (2016) model how reminders can mitigate undersaving caused by limited attention to future expenses. We draw on this attention channel and summarize its effect through an additive term, separately from reference-dependent utility and implementation costs.

¹⁴We specify these indices as functions of the assigned message, without imposing the consistency between expectations and choices required by Kőszegi and Rabin (2006). O'Donoghue and Sprenger (2018) review alternative approaches to reference-point formation. Appendix A allows initial levels e_0 and p_0 , which need not be zero, and represents ownership and planning content as nonnegative shifts δ_E and δ_P in the corresponding indices.

¹⁵In the model of Reis (2006), forming and updating plans require resources. This motivates allowing a suggested vaccination time to save parents the effort of choosing when to act. Because parents remain free to attend at another time, an inconvenient suggestion need not raise implementation costs if the parent ignores it and retains any existing arrangements. A negative ω_i requires an additional response, such as displacing a feasible arrangement and leaving the parent to coordinate a new visit.

¹⁶In the utility specification in Appendix A, $\kappa_i(t)$ lowers the payoff from completing the schedule. A nuisance from receiving an SMS that affects completion and noncompletion equally would cancel from the comparison and would not change the action threshold. We use this term to represent that possible burden separately from the net implementation effect of the suggested time, ω_i .

The parent has reference-dependent preferences over the entitlement and plan dimensions. In this binary framework, completing the schedule entails no reference loss; we abstract from deviations from the suggested vaccination time. If she does not complete the schedule, she falls short of the reference points created by the message. Let $L_i(e, p)$ denote this reference-dependent loss, with $L_{i,e}(e, p) \geq 0$ and $L_{i,p}(e, p) \geq 0$, and let $\lambda_i > 0$ be the weight placed on such losses.¹⁷ The parent completes the schedule under treatment t if

$$\theta_i + \Gamma_i(t) \geq 0, \tag{1}$$

where

$$\Gamma_i(t) = s_i(t) + \omega_i a(t) - \kappa_i(t) + \lambda_i L_i(e(t), p(t)). \tag{2}$$

Equation (1) shows that the interventions affect completion by shifting marginal parents across the action threshold. Parents with very high values of θ_i complete the schedule even without a message, while parents with very low values of θ_i do not complete even after receiving one. Messages can change completion decisions by shifting attention, reference points, or implementation costs among parents close enough to the action threshold. The experiment studies this response among parents whose daughters had initiated but not completed the HPV vaccination schedule.¹⁸

The model clarifies the interpretation of the experimental comparisons. The placebo message provides a benchmark for the common features of receiving a personalized message from the Health Secretariat. The ownership reminder adds an entitlement reference point by stating that the vaccine is reserved for the daughter. The planning-prompt treatment adds a plan reference point by suggesting a specific day and time for vaccination and may

¹⁷Our binary formulation retains the loss component of reference-dependent preferences (Tversky and Kahneman, 1991; Köszegi and Rabin, 2006). We impose $L_i(0, 0) = 0$ so that noncompletion generates no reference loss when neither reference is present; the nonnegative partial derivatives mean that strengthening either reference cannot reduce this loss.

¹⁸For a treatment t that raises the completion incentive relative to the pure control C , a parent switches to completion when $-\Gamma_i(t) \leq \theta_i < -\Gamma_i(C)$. Being marginal therefore depends on both the initial decision margin and the shift induced by the message.

reduce the cost of deciding when to act. The combined treatments activate both reference points, but their effect on completion need not equal the sum of the effects of ownership and planning alone.¹⁹

The ranking between ownership reminders and planning prompts is therefore theoretically ambiguous. Ownership reminders can be more effective if noncompletion reflects weak entitlement or if parents respond strongly to the possibility of losing a reserved good. Planning prompts can be more effective when parents intend to complete the schedule but fail to choose and execute a specific moment for doing so. The empirical ranking identifies the relative effectiveness of the implemented messages. A larger planning effect is consistent with planning and implementation frictions, but may also reflect the plan reference point or differences in salience. A larger ownership effect is consistent with a stronger response to perceived entitlement. Because the experiment does not measure these psychological processes or how strongly each message activates them, the ranking cannot establish which friction is more binding. Appendix A presents the full derivation and proofs.

3 Background

Cervical cancer remains one of the most important preventable causes of mortality among women in developing countries. In 2020, approximately 342,000 women died from cervical cancer, and close to 90% of these deaths occurred in low- and middle-income countries (Sung et al., 2021). Persistent infection with the human papillomavirus (HPV) is the main cause of cervical cancer, explaining more than 95% of cervical cancer cases (WHO, 2022). The availability of HPV vaccines therefore created an extraordinary opportunity to prevent a large share of this disease burden. However, the returns to this preventive investment depend on completing the vaccination schedule. This distinction is central for our study. Low vaccination

¹⁹Proposition A5 in Appendix A decomposes shifts in individual incentives. Reference-point interactions and message-burden costs can make these shifts nonadditive. Even when the shifts are additive, completion effects need not be: each message may move some of the same parents across the threshold, while the combination may induce others to act who would not respond to either message alone. Aggregate effects therefore depend on the distribution of parents around the threshold as well as on the incentive shifts.

coverage can reflect low initial demand, but incomplete schedules among girls who already received a first dose reveal a different problem: households may start a valuable preventive investment and still fail to complete it.

Colombia provides a useful setting to study this margin. At the time of the experiment in 2022, HPV vaccination was available free of charge to girls aged 9–17 through the Expanded Program on Immunization (PAI).²⁰ The country initially achieved unusually high levels of HPV vaccination after introducing a national school-based campaign in 2012. According to Nogueira-Rodrigues (2019), Colombia reached a first-dose HPV vaccination coverage rate of 97.5% in 2013, the second-highest rate worldwide after Australia. The school-based model was important because it reduced the costs of acting for households. Parents did not need to search for a vaccination point, choose a date, coordinate transportation, or remember a future visit in the same way they would under a facility-based model. In this sense, the original design of the campaign compressed many of the implementation frictions that usually prevent preventive health investments from being completed.

This trajectory changed after the events in Carmen de Bolívar in 2014. Around 500 girls who had recently received the HPV vaccine reported symptoms such as headaches, fainting, and numbness of extremities. Some families and anti-vaccine groups attributed these events to the HPV vaccine, generating a public controversy around the program. Subsequent epidemiological work by the Colombian Ministry of Health and Social Protection and the National Institute of Health found that it was not plausible to associate HPV vaccination with the events in Carmen de Bolívar (Martínez et al., 2015). This conclusion is consistent with the international evidence.²¹ Nevertheless, the episode changed the environment in which HPV vaccination decisions were made. The vaccine became more contested, the school-based

²⁰During the 2022 campaign, the schedule consisted of two doses six months apart, and the Health Secretariat invited families to attend vaccination sites without an appointment (Barreto, 2022). National guidance also provided for vaccination at public and private sites regardless of insurance affiliation (Ministerio de Salud y Protección Social de Colombia, 2015). Free access therefore did not eliminate the time and coordination required for a return visit.

²¹For example, Phillips et al. (2018) review 109 studies and conclude that HPV vaccines have an acceptable safety profile.

delivery strategy was disrupted, and a subsequent Constitutional Court ruling reinforced the requirement for informed consent.²²

These institutional features matter for our research question because completion involves both authorization and follow-through by households. Completing the HPV vaccination schedule therefore required parents to pay attention to the pending dose, decide when to go, coordinate the visit, and execute the action after some delay. This is precisely the type of setting in which completion failures may arise even when households are not opposed to vaccination. A parent may value the vaccine and still postpone the visit, forget the relevant date, fail to coordinate the logistics, or never transform a general intention into a specific plan.

The decline in HPV vaccination coverage after Carmen de Bolívar was substantial. By 2016, coverage had fallen to 14% for the first dose and 5% for the complete course (Simas et al., 2019). Although different institutions have attempted to restore confidence and increase uptake, progress has been uneven.²³ Despite these efforts, national coverage remained low. In 2019, first-dose coverage was 34.1% nationally, while second-dose coverage was only 11.1%. The situation was even more pronounced in Bogotá, where first-dose coverage was 25.7% and second-dose coverage was only 6% (Ministerio de Salud y Protección Social de Colombia, 2020). These figures indicate that the second-dose margin is not a minor administrative problem. It is a central component of the low-protection equilibrium that emerged after the collapse of the original campaign.

Our experiment focuses on this completion margin. The target population consists of parents whose daughters had already received the first dose of the HPV vaccine but had not

²²Vorstters et al. (2020) describe the retreat from school-based HPV vaccination after the Carmen de Bolívar crisis and identify restoring school delivery as a policy priority. In Judgment T-365/17, the Constitutional Court reaffirmed that HPV vaccination is voluntary and required prior informed consent from recipients and, for minors, their parents or legal representatives (Corte Constitucional de Colombia, 2017). The ruling established a procedural requirement; it did not estimate its effect on vaccination coverage.

²³For example, the Arauca initiative led by the Liga Colombiana Contra el Cáncer engaged girls, parents, teachers, healthcare providers, and local media through tailored information materials, talks, and training for health personnel. Reported first-dose coverage rose from about 5% in 2017 to 41% in 2018 and 83% in 2019 (Castro et al., 2020).

completed the schedule. This feature matters for interpretation. These households are not equivalent to households that never initiated vaccination. By accepting the first dose, they revealed some willingness to vaccinate, which makes noncompletion more consistent with follow-through frictions than with complete rejection of the vaccine. This setting therefore allows us to study whether light-touch messages can help households complete a preventive health investment that has already been initiated.

The comparison between ownership reminders and planning prompts is motivated by this context. Ownership reminders may increase completion if parents respond to the idea that the vaccine has been reserved for their daughter and that not returning implies failing to claim an assigned good. Planning prompts may increase completion if the relevant barrier is instead the absence of a concrete plan. By making a specific day and time focal, these messages can help parents transform a general intention to vaccinate into an actionable step. In this sense, Bogotá and the surrounding areas provide a natural setting to test whether second-dose completion is more responsive to entitlement-based reminders or to interventions that reduce planning and implementation frictions.

4 Research design

4.1 The intervention

The intervention was developed with the Bogotá Health Secretariat, the Liga Colombiana Contra el Cáncer, the Inter-American Development Bank, the American Cancer Society, and the Universidad del Rosario. It targeted parents or guardians of girls who had received a first HPV vaccine dose but had not completed the schedule. This population had revealed some demand for vaccination, but completing the investment still required a subsequent action. We used SMS because the Health Secretariat already relied on this channel and could link its communication system to administrative immunization records. The intervention therefore changed the content of an existing public-sector tool rather than creating a parallel delivery system.

The campaign ran for six weeks, from May 4 to June 11, 2022. Messages were delivered in weekly cycles, and parents stopped receiving them once the administrative records showed that their daughters had completed the schedule.²⁴ All message conditions shared two features: the SMS was personalized with the recipient’s first name and identified the Health Secretariat as the sender. These elements held personalization and the institutional source constant while the experimental arms varied the behavioral content. Figure 1 summarizes the design, implementation, and administrative follow-up sequence.

The experiment included six conditions: a pure control, a placebo message, an ownership reminder, a planning prompt, and two treatments combining the planning prompt with ownership language. Table 1 summarizes the conditions, and Figure A-2 reproduces the messages. Parents in the pure control received no SMS. Those assigned to the placebo received a personalized message from the Health Secretariat with general recommendations for protecting their mental health, but no reference to HPV, vaccination, or their daughter’s incomplete schedule. The placebo thus retained institutional contact and personalization without drawing attention to the vaccination decision.

The ownership treatment told the parent that “there is an HPV vaccine reserved for your daughter.” The wording adapted the reservation message studied by Milkman et al. (2021) to a decision made by a parent on behalf of a child. It framed a vaccine dose as assigned to the daughter, while leaving the parent responsible for deciding when and where to complete the schedule. The treatment consequently combined a reminder about the pending dose with language intended to create a sense of entitlement over the vaccine.

The planning treatment used appointment language to suggest a specific Saturday at 10 a.m. for vaccination. Saturday was selected because vaccination sites were operating and parents were expected to face fewer work-related constraints. We describe this treatment as

²⁴Each weekly cycle comprised one SMS in the placebo, ownership-only, and planning-only arms and two SMS in each combined arm. Over six cycles, these schedules implied a maximum of six and twelve messages per parent, respectively. The realized number could be lower because messaging stopped after completion appeared in the administrative records.

a planning prompt because it translated an open-ended intention into a concrete day and time while leaving parents free to decide when and where to vaccinate.²⁵

The two combined treatments first delivered the planning prompt and then followed it with the ownership reminder. The second message arrived either 24 hours or two hours before the suggested vaccination time. Because the content and number of messages were the same across these two arms, their comparison isolates whether bringing the ownership cue closer to the intended action changes the response. Comparisons between a combined arm and the planning-only arm have a different interpretation, since they vary both ownership content and the number of contacts.

4.2 Estimands, reminder effects, and comparison groups

The six-arm design supports several estimands with different substantive meanings. Our principal benchmark is the pure control. Comparisons with this group identify the intention-to-treat effect of assigning each complete communication package relative to receiving no SMS. The resulting estimates include the behavioral content of the active message as well as any response to being contacted, receiving a personalized communication from the Health Secretariat, and having the pending HPV dose made salient. This estimand is the most relevant for a health authority deciding whether to add the message package to its existing vaccination activities.

The placebo provides a second counterfactual. Its comparison with the pure control tests whether a personalized Health Secretariat message about an unrelated health topic changes HPV completion. Comparisons between an active treatment and the placebo instead recover the incremental effect of an HPV-specific communication relative to institutional contact without HPV content. The latter contrast does not isolate ownership or planning from the effect of reminding parents about HPV and their daughter’s incomplete schedule, because the

²⁵The SMS used the word “appointment,” but the implementing institutions did not schedule individual appointments or reserve slots at particular facilities. Vaccination remained free, and parents could attend any participating site at another time. Thus, the message made a suggested time salient without changing access or the formal choice set; inaction still resulted in non-vaccination.

placebo is not a generic HPV reminder. We therefore use the placebo to assess contact and common message features rather than as the sole benchmark for the behavioral mechanisms.

The PAP also specified a pooled comparison group that combines the pure and placebo controls. Pooling improves precision by increasing the size of the benchmark, but it merges two counterfactuals with different interpretations. We consequently report pooled-control estimates as robustness checks. At the aggregate level, we first estimate the effect of assignment to any of the four active messages relative to the pure control. We then use the arm-specific estimates to determine whether this average masks differences across ownership, planning, and combined communication strategies.

The ownership-only and planning-only arms provide the cleanest comparison of the two active message packages. Both groups received one personalized HPV message from the same institutional sender, so their difference identifies the relative effectiveness of the implemented contents. It does not directly identify the psychological process responsible for that difference. Similarly, comparing the planning-only arm with either combined arm assesses whether adding the ownership reminder produces further gains, but the contrast varies both behavioral content and the number of contacts. Only the comparison between the two combined arms holds content and contact frequency constant while changing the timing of the ownership reminder.

The PAP pre-specified positive effects for the individual messages and for assignment to any active message. It also anticipated complementarity between planning and ownership and specified comparisons using the pure, placebo, and pooled controls. The directional ranking between planning prompts and ownership reminders was not pre-specified. We treat that ranking as a theory-guided contrast supported by the original experimental design, while distinguishing it from the PAP’s confirmatory hypotheses.

4.3 Experiment

The unit of random assignment was the parent or guardian contact associated with an eligible girl. The final sample contains 5,907 randomized parent records, each linked to one eligible

daughter and assigned to one of the six mutually exclusive conditions reported in Table 1 and Figure 3. Throughout the paper, we refer to parents as the experimental participants because the messages were directed to them and they made the vaccination decision; completion outcomes are measured for their daughters. Assignment was divided almost equally across the arms: 985 parents entered the pure control, 985 the placebo, 983 the ownership arm, 986 the planning arm, and 984 each of the two combined arms. In total, 1,970 parents were assigned to a control condition and 3,937 to an active message.

We implemented a blocked randomized design using the cross-product of baseline location and the girl’s age group. Location distinguishes girls inside Bogotá from those outside the city, while the age indicator separates girls ages 9–10 from those ages 11–17. These variables were available before treatment and were expected to predict vaccination behavior. Within the four strata, assignment followed the rerandomization procedure proposed by Morgan and Rubin (2012). Candidate allocations were evaluated using the main health-insurer indicators and health-system regimes before the final assignment was selected.²⁶ Section 4.5 assesses balance using the broader set of administrative covariates available for the experimental sample.

The experiment and analysis plan were registered in the AEA RCT Registry before the final outcome data were requested and analyzed. The intervention was implemented within the Health Secretariat’s regular public-health communication activities, and the institutional review board at Universidad del Rosario approved the protocol under study DVO005 1663-CV1287. The research team handled parent and vaccination records under the confidentiality protections applicable to the administrative data.²⁷

²⁶Blocking and rerandomization serve related but distinct purposes. Crossing the two location categories with a binary age group avoids fragmenting the sample into many age-specific cells. Rerandomization then uses additional baseline information to improve balance within this design (Morgan and Rubin, 2012). The assignment script evaluated indicators for Sanitas, Salud Total, Famisanar, Compensar, and Capital Salud, together with contributory-regime, subsidized-regime, and uninsured status. These are the covariates used to select the allocation; Section 4.5 assesses balance on the broader set of observed baseline characteristics.

²⁷The PAP also described proposed experiments among parents of unvaccinated girls. Institutional restrictions prevented their implementation. The present paper examines only the experiment conducted among parents of girls with incomplete vaccination schedules.

Treatment assignment does not ensure that the registered telephone number was active or that the recipient read the SMS. The delivery system does not allow us to establish exposure at the individual level, so all estimates are interpreted as intention-to-treat effects of assignment to a message. Unobserved delivery or reading failures may attenuate the estimates. They do not threaten the internal validity of the randomized comparisons unless the probability of exposure differs systematically across assigned conditions for reasons induced by the treatment.

Administrative records allow us to observe the outcome for the full randomized sample without relying on a follow-up survey.²⁸ This feature limits conventional attrition and avoids self-reported vaccination measures. At the same time, the outcome captures only doses reported through the administrative information system. The estimates should therefore be interpreted as effects on recorded completion, which is the outcome available to the implementing health authority.

4.4 Data and sample

The study combines randomized assignments with administrative records from the Bogotá Health Secretariat. Vaccination providers report HPV doses to PAIWEB, the information system of Colombia’s Expanded Program on Immunization. These records indicate whether an eligible girl received the second dose and provide the corresponding date. The administrative data also contain the baseline variables used in the analysis: the girl’s age and location, health insurer, health-system regime, nationality, recorded ethnicity, and displacement status. All were measured before assignment and are defined in Appendix Table A-1. Although the intervention was implemented with the Bogotá Health Secretariat, the resulting records include girls located both inside and outside Bogotá.

The target population consisted of parents of girls ages 9–17 who had received one

²⁸In their review of COVID-19 vaccination interventions, Batteux et al. (2022) found that 32 of 39 studies measured intentions and seven measured behavior, including vaccination rates or scheduled appointments. Our administrative outcome records completion of the second HPV dose.

HPV vaccine dose but had not completed the schedule. Eligibility also required enough information to identify a parent or guardian and a telephone number for delivering the SMS. We constructed the sampling frame from Health Secretariat records that had not been included in an earlier program of HPV vaccination experiments. These records had been excluded because of geographic restrictions, missing locality information, or an insufficient interval between doses when the earlier frame was assembled.²⁹

Figure 2 traces the construction of the sample. The original administrative frame contained 100,465 girls with incomplete schedules. Of these, 7,412 records excluded from the earlier program for the reasons described above were reconsidered for the present experiment. We then removed 1,464 girls who completed the schedule before implementation, 29 who had turned 18, and 12 records with duplicate or invalid telephone numbers. These exclusions yielded the final sample of 5,907 parent records.

The primary outcome equals one when PAIWEB records completion of the second HPV dose during the analysis window. The dataset contains 819 completions among the 5,907 randomized observations and retains the exact vaccination date for the dynamic analysis. We measure completion from April 25 through July 30, 2022. The window begins shortly before the first SMS on May 4 and extends seven weeks beyond the final delivery on June 11, allowing us to examine both pre-campaign differences and the persistence of the treatment effects. The administrative records provide one additional week of follow-up beyond the period specified in the PAP. We use the full window to take advantage of all available outcome data; excluding the additional week leaves the magnitude, ranking, and statistical interpretation of the central treatment estimates unchanged.

Administrative measurement provides broad outcome coverage and avoids relying on self-reports, but it also defines the boundaries of the analysis. The sample excludes records

²⁹The earlier program evaluated several communication strategies among families of unvaccinated girls and girls with incomplete schedules. For the present experiment, the records reconsidered included girls outside Bogotá, girls in Sumapaz, records without locality information, and girls who had not yet satisfied the six-month interval between doses. We updated eligibility before implementation.

without usable parent or telephone information, and PAIWEB contains few socioeconomic or attitudinal characteristics. We cannot directly observe household income, parental education, vaccine beliefs, or planning constraints. These restrictions limit external-validity and mechanism analyses, although they do not alter the internal validity of treatment comparisons within the randomized sample.

4.5 Summary statistics and pre-treatment balance

Table 2 describes the 5,907 girls in the experimental sample. Their average age was 11.25 years, 46.1% were ages 9–10, and 62.8% were located inside Bogotá. Age and location also defined the randomization strata. Most girls were enrolled in the contributory health-insurance scheme (81.3%), while 12.3% belonged to the subsidized scheme, 1.3% were recorded as uninsured, and 5.1% belonged to another regime. The sample was predominantly Colombian (96.3%); 0.5% were recorded as belonging to an ethnic group and 1.2% as displaced by the armed conflict.

The small shares of uninsured girls, ethnic-group members, and displaced girls limit the precision of subgroup estimates along these dimensions. More generally, the administrative records do not contain household income, parental education, vaccine beliefs, or direct measures of planning constraints. The descriptive statistics therefore characterize the dimensions observed by the health authority, but they cannot establish how the experimental sample compares with eligible households along unmeasured socioeconomic characteristics or attitudes.

The randomization produced comparable groups on the available baseline variables. We calculate signed standardized differences between each non-pure-control arm and the pure control. All absolute differences are below 0.1, and the largest is approximately 0.075.³⁰ Table 2 and Figure 4 provide the complete results. Appendix Table A-2 and Appendix Figure A-3 repeat the exercise using the placebo as the benchmark; the differences again remain

³⁰As a point of reference, Imbens (2015) describes normalized differences of up to 0.3 as modest in his analysis of experimental data. Our covariates satisfy the more stringent balance criterion of 0.1.

below 0.1 in absolute value.

These checks support the successful implementation of the blocked rerandomization procedure, and the conclusion does not depend on whether the pure or placebo control serves as the reference group. They cover every pre-treatment characteristic available in the administrative records. As in any randomized design, balance in observed covariates does not demonstrate balance in each unobserved characteristic, but random assignment provides the basis for causal inference within the experimental sample.

5 Empirical model

5.1 Basic model

We estimate intention-to-treat effects using linear probability models.³¹ The outcome, y_{ij} , equals one if PAIWEB indicates that vaccinee i , linked to parent j , completed the second HPV vaccine dose during the analysis window and zero otherwise. Random assignment identifies the causal effect of assignment to each SMS condition within the experimental sample. The estimand is not the effect of reading a message, since individual exposure is unobserved, but the policy-relevant effect of assigning the communication package through the Health Secretariat’s delivery system.

Our arm-specific specification is

$$y_{ij} = \alpha + \lambda P_j + \sum_{k=1}^K \beta_k Z_j^k + \theta_S + X'_{ij} \delta + \varepsilon_{ij}. \quad (3)$$

In Equation (3), P_j indicates assignment of parent j to the placebo condition, while Z_j^k contains indicators for the four active treatments: the ownership reminder, the planning prompt, and the two combined arms with different reminder timings. The term θ_S represents fixed effects for the randomization strata defined by location and age group, while X_{ij} contains

³¹Our outcome is binary, so differences in mean completion rates correspond to differences in vaccination probabilities. The linear specification expresses treatment contrasts directly on this scale and facilitates tests comparing the experimental arms. See Angrist (2001) for a discussion of linear models for estimating causal effects with limited dependent variables.

pre-treatment administrative covariates for vaccinee i and parent j .

The pure control is the omitted category. The coefficient λ therefore captures the effect of the placebo message relative to receiving no SMS, while each β_k measures the effect of assignment to active treatment k relative to the pure control. We estimate the model on the original 0–1 outcome scale and multiply the coefficients by 100 when reporting percentage-point effects. All specifications include the four randomization-strata fixed effects. The preferred model additionally controls for age in years; indicators for the main health insurers and health-system regimes; and indicators for ethnicity, displacement status, and Colombian nationality. These controls can improve precision, but identification follows from random assignment rather than covariate adjustment.³²

Inference uses Eicker–Huber–White heteroskedasticity-robust standard errors. Assignment occurred at the parent-contact level, and each randomized parent record contributes one eligible girl. Household clustering therefore offers no meaningful additional correction under the effective individual-level structure of the data (Abadie et al., 2023). The dynamic specifications described below are different because each girl contributes repeated weekly observations; for those models, we cluster standard errors at the girl level.

We first summarize the experiment with an aggregate specification. This model replaces the four active-arm indicators with A_j , an indicator for assignment to any active message, while retaining a separate indicator for the placebo. The coefficient on A_j estimates the average effect of the active-message family relative to the pure control. Arm-specific estimates then show whether this average conceals differences across ownership, planning, and combined packages.

We next reparameterize Equation (3) to map the experimental arms into the conceptual framework. The specification retains the placebo indicator and replaces the four active-treatment indicators with the ownership cue, the planning prompt, their interaction, and the

³²We report both the strata-only and covariate-adjusted estimates so that the contribution of the adjustment set remains transparent.

contrast between the two-hour and 24-hour reminders. The indicator for assignment to any active message is not included because it is exactly collinear with the ownership, planning, and interaction terms. This parameterization allows us to compare τ_O with τ_D and to assess whether the combined treatment satisfies $\tau_{OD} = \tau_O + \tau_D$. We use linear contrasts to test equality between the ownership and planning coefficients, whether the interaction is zero, and whether reminder timing matters. We also test equality across all active arms and across the three arms containing a planning prompt.³³

The dynamic analysis examines when the treatment effects emerge and whether they persist after message delivery. We reshape the data into a stacked girl-week panel covering the 14 calendar weeks ending April 30 through July 30, 2022. The weekly outcome indicates whether the girl had completed the second dose by the end of each week. We estimate arm-specific effects relative to the pure control using treatment-by-week interactions, week fixed effects, randomization-strata fixed effects, and the preferred baseline covariates. Standard errors are clustered at the girl level to account for repeated observations.

Kaplan–Meier-style curves provide a descriptive complement to the weekly regressions. Every observation shares the same administrative end date, and the data contain no differential censoring. The curves should consequently be read as cumulative vaccination rates by date rather than as estimates of a separate duration-model parameter. Their role is to show the timing and persistence of completion, not to change the causal estimand defined by assignment to treatment.

5.2 Robustness checks

We assess whether the main findings depend on the covariate set or estimator. The strata-only specification relies on the randomized design, whereas the preferred model adds all available

³³The ownership-by-planning coefficient measures the departure from additivity for the combined arm with a 24-hour reminder. The two-hour reminder coefficient captures the difference between the two combined arms, so the departure from additivity for the two-hour arm is the sum of these coefficients. Because the combined arms include a second contact, the interaction should not be interpreted as a pure psychological interaction between ownership and planning.

baseline administrative controls. Similar estimates across these models would indicate that the results are not driven by adjustment choices. Because the PAP did not fully determine which baseline variables should enter the adjusted model, we also implement double-selection LASSO (Belloni et al., 2014). Treatment indicators and randomization-strata fixed effects remain variables of interest, while the procedure selects predictive controls from the same administrative covariate set.³⁴

We assess the sensitivity of the arm-specific estimates to the contamination bias described by Goldsmith-Pinkham et al. (2024).³⁵ We also change the omitted comparison group, re-estimating the models relative to the placebo and to the pooled pure-plus-placebo control. These specifications implement the estimands described in Section 4.2 while retaining the same strata fixed effects, baseline controls, and robust standard errors.

Multiple treatment arms create a second inferential concern. Following the PAP, we apply the Benjamini–Hochberg false-discovery-rate procedure (Benjamini and Hochberg, 1995) to the five contrasts comparing the placebo and the four active treatments with the pure control. Appendix Table A-4 reports Benjamini–Hochberg and two-stage sharpened false-discovery-rate q -values for the pure-control, placebo-control, pooled-control, and mechanism-contrast families.³⁶ We complement this correction with stratified randomization inference.³⁷

³⁴The procedure selects controls through separate LASSO regressions for the vaccination outcome and each variable of interest. The final outcome regression includes the union of the controls selected in these regressions. A covariate can therefore enter the adjustment set through its predictive relevance for either the outcome or the variables of interest.

³⁵With multiple treatments and heterogeneous effects, a covariate-adjusted regression coefficient can include contributions from other treatments’ effects. We estimate the own-treatment effect component (OWN) by subtracting an estimate of those contributions from the partly linear coefficient. This retains the weighted component associated with the treatment of interest. Comparing OWN with the conventional estimates assesses the sensitivity of our results to contamination bias.

³⁶False discovery rate control limits the expected proportion of false rejections among rejected hypotheses, whereas familywise error control limits the probability of at least one false rejection. This less stringent criterion can improve power when evaluating several potentially effective message strategies. For each procedure, a reported q -value is the smallest FDR level at which a hypothesis is rejected within its testing family. The two-stage sharpened q -values use the adaptive procedure of Benjamini et al. (2006), which estimates the number of true null hypotheses, following the implementation described by Anderson (2008).

³⁷The sharp null states that each girl’s vaccination outcome is the same under all experimental conditions. Under this hypothesis, observed outcomes remain fixed when treatment labels are reassigned. The permutation p -value measures how often the resulting statistic is at least as extreme as the observed one. This provides a complementary assessment of statistical significance to conventional inference based on robust standard

Treatment assignments are permuted 10,000 times within the original strata, and two-sided p -values compare the absolute robust t -statistic under the observed allocation with its permutation distribution. Figure 7 reports these distributions and the observed estimates.

We examine treatment-effect heterogeneity using conventional subgroup interactions and machine-learning methods. The conventional analysis excludes the placebo and compares the four active arms with the pure control. For a pre-treatment characteristic W_j , we estimate

$$y_{ij} = \alpha + \sum_{k=1}^K \beta_k Z_j^k + \gamma W_j + \sum_{k=1}^K \phi_k (Z_j^k \cdot W_j) + \theta_S + X'_{ij} \delta + \varepsilon_{ij}, \quad (4)$$

where ϕ_k captures how the intention-to-treat effect of active treatment k varies with W_j . We first interact each characteristic with an indicator for any active treatment and then estimate arm-specific interactions. The models otherwise retain the strata fixed effects, baseline controls, and robust standard errors used in the preferred ITT specification.

The subgroup dimensions are age 9–10, residence inside Bogotá, subsidized or uninsured status, Colombian nationality, and displacement by armed conflict. The PAP anticipated heterogeneity by health regime, insurance access, nationality, ethnicity, and displacement. Age and location defined the randomization strata but were not accompanied by directional heterogeneity hypotheses. We therefore interpret their interactions as additional design-based analyses rather than confirmatory tests of pre-specified directional predictions. Ethnicity does not appear in the main heterogeneity table because only 0.5% of the sample is recorded as belonging to an ethnic group. Estimates for nationality and displacement also require caution because the smaller side of each comparison contains few observations.³⁸

The GenericML framework of Chernozhukov et al. (2025) provides a more flexible assessment of treatment-effect heterogeneity. This analysis compares assignment to any active message with the pure control and excludes the placebo. The best linear predictor (BLP)

errors.

³⁸These limitations concern the precision and interpretation of subgroup estimates, not identification of the average treatment effects in the full randomized sample.

assesses whether the predicted treatment-effect score captures variation in treatment effects. Group average treatment effects (GATES) summarize effects across five groups ranked by predicted gains, while classification analysis (CLAN) compares the baseline characteristics of the groups with the lowest and highest predicted gains.³⁹

All estimates rely on the standard no-interference assumption. The administrative records do not contain communication networks among parents, so the study cannot measure whether recipients shared message content with control households. Such diffusion would reduce the difference in exposure between experimental conditions and would generally attenuate the estimated intention-to-treat contrasts. The available data do not allow us to test this possibility directly.

6 Results

6.1 Main results for the aggregate message treatment

Assignment to any of the four active messages increased second-dose completion by 7.57 percentage points relative to the pure control group, with a standard error of 1.06 percentage points. This effect is large relative to the pure-control completion rate of 8.63 percent: it represents an increase of approximately 88 percent over the control mean. The estimated gain is also large relative to average effects reported in other vaccination messaging experiments.⁴⁰ Panel A of Table 4 reports this aggregate estimate. Its magnitude is remarkably stable across the alternative specifications described in Section 5, ranging from 7.53 to 7.57 percentage

³⁹For each split, one half of the sample is used to train predictions from baseline characteristics, and the other half is used to estimate BLP, GATES, and CLAN. This separation limits overfitting in the assessment of treatment-effect heterogeneity. We use 100 sample splits and four learners: random forest, cross-validated elastic net, support vector machine, and XGBoost. Repeating the split reduces dependence on any single partition. The PAP contemplated GenericML if sufficient baseline information became available, but it did not specify the final learners, number of splits, or reporting choices. We therefore treat the implemented analysis as structured supplementary evidence rather than a fully specified confirmatory test.

⁴⁰As a point of reference, Maldonado et al. (2026) estimate that social-norm messages increase first-dose HPV vaccination by 0.907 percentage points, or 16.3 percent relative to a control mean of 5.56 percent. Average increases in influenza vaccination are 1.8 percentage points in Patel et al. (2023) and 2.0 points in Milkman et al. (2022), while Busso et al. (2015) report a 2.2-point increase in age-appropriate childhood vaccination in Guatemala. The studies differ in vaccines, baseline uptake, control conditions, and follow-up periods; our estimate concerns second-dose completion among families that had already initiated vaccination.

points as we add pre-treatment covariates or use double-selection LASSO.

The placebo message increased completion by 1.43 percentage points relative to the pure control, but the estimate is not statistically different from zero. Thus, the data provide no evidence of a contact-only effect comparable in magnitude to the effects of the active messages, although the confidence interval does not rule out a smaller response.⁴¹ The aggregate effect nevertheless masks substantial variation across message content. We next examine the arm-specific estimates to compare ownership reminders with planning prompts.

6.2 The effects of ownership reminders versus planning prompts

The arm-specific estimates show that both behavioral approaches increased second-dose completion, but planning prompts produced a larger response. Table 3 reports the intention-to-treat effects for each experimental arm. In the preferred covariate-adjusted specification, the ownership reminder increased completion by 4.58 percentage points, while the planning prompt increased it by 8.67 percentage points.⁴² Both estimates are statistically significant at the one-percent level. Relative to the 8.63-percent pure-control mean, the ownership reminder increased completion by approximately 53 percent, whereas the planning prompt approximately doubled it. A direct test rejects equality between the two treatment effects ($p = 0.010$).

Combining the planning prompt with an ownership reminder did not generate larger effects. The combined treatment increased completion by 7.94 percentage points when the ownership reminder arrived 24 hours before the suggested vaccination time and by 9.10 percentage points when it arrived two hours before. These estimates are close to the effect of

⁴¹Because the placebo message did not mention HPV vaccination, this comparison does not isolate a generic vaccination-salience effect. It instead captures the effect of contact with the health authority through a message unrelated to HPV vaccination.

⁴²Our planning estimate of 8.67 percentage points is about twice the 4.2-point gain from date-and-time prompts in Milkman et al. (2011), where the comparison group received a standard reminder mailing. The 4.58-point ownership estimate is close to the 4.6-point gain from the best reservation-message package in the primary-care megastudy of Milkman et al. (2021) and above the corresponding 2.9-point gain in the pharmacy megastudy of Milkman et al. (2022). Using the full observation period of the primary-care experiment, Patel et al. (2023) report a 3.1-point gain for the best reservation package.

the planning prompt alone. Indeed, the null hypothesis that the three treatments containing a planning prompt have equal effects cannot be rejected ($p = 0.778$). The evidence therefore indicates that neither adding ownership language nor changing the reminder timing produced a detectable improvement over the planning prompt.

The magnitudes and ranking of these estimates remain stable across the alternative specifications described in Section 5, including the OWN estimates. The larger effects of the treatments containing a planning prompt are consistent with planning and implementation frictions being more binding than entitlement frictions among parents at the margin of completing the vaccination schedule. This interpretation is necessarily bounded by the experimental design. The treatment contrasts identify differences between the implemented message packages, but the experiment does not directly measure the psychological processes activated by either message.

6.3 Disentangling the effects of ownership reminders and planning prompts

Panel B of Table 4 uses the factorial structure of the experiment to separate the ownership and planning components. The specification includes an ownership cue, a planning prompt, their interaction, and an indicator distinguishing the two-hour from the 24-hour reminder. This parameterization maps the experimental arms into the entitlement and plan-reference components of the conceptual framework. The estimated ownership coefficient is 4.58 percentage points, while the planning coefficient is 8.67 percentage points. Their statistically significant difference of 4.09 percentage points confirms that the planning-prompt package generated a larger response than the ownership-reminder package. This comparison is consistent with the planning content adding value, although it does not isolate the underlying psychological channel from other differences between the implemented messages.

The interaction between the ownership cue and the planning prompt is negative and statistically significant. In the preferred specification, the interaction is -5.30 percentage points, with a standard error of 2.15 percentage points and a p -value of 0.014. The observed

effect of the combined 24-hour treatment is therefore approximately equal to the sum of the ownership and planning coefficients net of this negative interaction. Put differently, combining the two components did not produce additive gains.⁴³

Reminder timing does not explain the absence of additional gains. Moving the ownership reminder from 24 hours to two hours before the suggested vaccination time increased completion by 1.16 percentage points, but the estimate is imprecise and not statistically different from zero ($p = 0.484$). The data therefore provide no evidence that bringing the ownership cue closer to the intended action improves completion. Taken together, these results suggest that the planning prompt accounts for most of the effect of the combined message packages.

6.4 Dynamics of the treatment effects

The treatment effects emerged during the SMS campaign and accumulated as parents had opportunities to complete the second dose. Figure 5 traces cumulative effects over the 14-week analysis window. Before the first SMS delivery, the estimated differences between each active treatment and the pure control are close to zero. The effects become visible during the campaign and increase over the subsequent weeks. Appendix Figure A-4 presents the corresponding trajectories relative to the placebo group, while Appendix Figure A-5 reports each active treatment separately relative to the pure control.

The dynamic estimates reproduce the ranking observed in the main intention-to-treat results. The ownership-reminder effect rises gradually and reaches approximately 4–5 percentage points by the end of the follow-up period. The planning-prompt effect grows more rapidly and reaches approximately 8–9 percentage points. The two combined-treatment series follow a similar trajectory and remain close to one another throughout the analysis window. This pattern reinforces the finding that adding an ownership reminder to the planning prompt did not produce a detectable additional gain.

⁴³The interaction should be interpreted as a departure from additivity within the implemented message bundles. Because the combined treatments added a second contact as well as ownership language, the design does not identify a pure psychological interaction between entitlement and planning reference points.

The treatment-control gaps persist through July 30, several weeks after the final SMS delivery. This persistence indicates that the messages did not merely shift vaccination to the suggested date; they increased cumulative completion over the administrative follow-up period. The dynamic ranking also mirrors the arm-specific estimates in Table 3, with larger effects for every treatment containing a planning prompt.

Figure 6 provides complementary evidence using cumulative completion curves. The planning-prompt and combined-treatment curves separate most clearly from the pure control, while the ownership-reminder curve lies between them. By the end of the window, the ordering of the curves is consistent with the arm-specific estimates in Table 3. Appendix Figure A-6 shows the same qualitative ordering when the placebo group or the pooled control group serves as the benchmark.⁴⁴

6.5 Additional results

The main findings are robust to alternative inference procedures. Table 5 reports Benjamini–Hochberg q -values for the five comparisons against the pure control. All four active-treatment effects remain significant ($q \leq 0.001$), while the placebo effect remains insignificant ($q = 0.274$). Stratified randomization inference preserves this pattern, with $p \leq 0.001$ for the active treatments and $p = 0.285$ for the placebo. The ownership–planning difference and their interaction also remain significant at the five-percent level after the Benjamini–Hochberg adjustment within the six-hypothesis family in Panel D of Appendix Table A-4 ($q = 0.015$ and $q = 0.017$, respectively). The correction therefore preserves both conclusions: planning has the larger effect, and the combined treatment produces less than additive gains.

Appendix Table A-3 further shows that the active-treatment effects remain positive and statistically significant when the placebo group or the pooled pure-plus-placebo group serves as the comparison category. These comparisons establish that the active message packages

⁴⁴Because all observations share the same administrative end date and there is no differential censoring, the Kaplan–Meier-style curves are equivalent to descriptive cumulative vaccination rates by date. They show that the active messages accelerated completion and increased its final level, but they do not identify a separate duration-model parameter.

generated effects beyond those of the placebo message. However, they do not identify which behavioral mechanism produced the difference.

The average effect of the active messages varies by age and place of residence. Table 6 reports an effect of 12.43 percentage points for girls aged 9–10, compared with 3.46 percentage points for older girls. The difference between the two groups is 8.97 percentage points. Similarly, the estimated effect is 10.13 percentage points for families residing inside Bogotá and 3.30 percentage points for those outside the city, a difference of 6.83 percentage points. Both differences are statistically significant at the one-percent level. Joint tests also reject the null that the four arm-specific interactions are zero for each dimension ($p < 0.001$). Appendix Figure A-7 summarizes the interaction estimates and their confidence intervals across the reported subgroup dimensions.

The data provide less evidence of systematic heterogeneity by subsidized or uninsured status or Colombian nationality. The pooled treatment effect is 10.50 percentage points larger among displaced girls; this difference is statistically significant (standard error 5.57). These estimates should be interpreted cautiously. The relevant comparison cells for nationality and displacement are small, and only 63 observations are recorded as displaced. The resulting imprecision means that the absence of statistically significant differences by insurance status and nationality cannot be interpreted as evidence of homogeneous effects along these dimensions.⁴⁵

The GenericML analysis provides complementary evidence on treatment-effect heterogeneity. The best linear predictor in Appendix Figure A-8 yields a positive heterogeneity coefficient ($\beta_2 = 0.717$, $p = 0.0141$), indicating that the predicted-gain score captures systematic variation in treatment effects. Figure 8 reports effects of 1.20 and 14.56 percentage points for the lowest and highest predicted-gain quintiles, respectively. Although the group-specific confidence intervals are wide, the estimated difference between the highest and lowest quintiles

⁴⁵Age and location defined the randomization strata, but the available PAP text did not state directional heterogeneity hypotheses for these dimensions. We therefore interpret the corresponding estimates as design-based subgroup evidence rather than as confirmatory tests of pre-specified directional hypotheses.

is positive and statistically significant (13.88 percentage points; $p = 0.0137$).⁴⁶

The classification analysis in Appendix Figure A-9 and Appendix Table A-5 shows that the group with the highest predicted gains includes younger girls (9.55 versus 13.92 years) and a larger share of families residing inside Bogotá (99.80 versus 6.04 percent). These profiles are consistent with the subgroup patterns reported above. Appendix Figure A-10 presents the alternative GATES-style implementation used as a robustness and quality-control exercise.

These machine-learning results should be viewed as structured supplementary evidence. The PAP did not fully specify the final implementation, and the administrative covariates do not include direct measures of household resources, vaccine beliefs, or planning constraints. The analysis can therefore document systematic variation in predicted treatment gains but cannot provide a complete account of the mechanisms behind that variation. This limitation is particularly relevant when interpreting the characteristics of the groups predicted to benefit most from the intervention.

7 Cost-effectiveness

The intervention generated additional second-dose completions at a low direct implementation cost. We assess cost-effectiveness from the perspective of the implementing government by combining the cost of the SMS campaign with the covariate-adjusted intention-to-treat effects reported in Section 6. The outcome is an additional girl completing the second HPV vaccine dose during the study period. Table 7 presents the cost assumptions and results, first for the campaign as a whole and then for each experimental arm.

The campaign required an estimated USD 162.38 in 2022 prices. SMS delivery accounted for USD 73.49: the intervention planned 41,340 messages at a unit cost of COP 8. The remaining USD 88.89 corresponds to ten hours of message programming and delivery, valued at COP 40,000 per hour. We convert all amounts using the exchange rate applied in the

⁴⁶Estimates are aggregated across the 100 sample splits using medians. The median of the between-group contrast can therefore differ from the difference between the two group medians (Chernozhukov et al., 2025).

original project calculations, COP 4,500 per USD.⁴⁷

A total of 4,922 participants were assigned to an SMS condition, including the placebo and the four active-message arms. Dividing total implementation costs by this population yields an average direct cost of approximately USD 0.033 per covered participant. Table 7 reports this amount rounded to USD 0.03, but the calculations use the unrounded value. For treatment k , we compute the cost per additional second-dose completion as

$$\hat{c}_k = \frac{C/N_{\text{SMS}}}{\hat{\tau}_k}, \quad (5)$$

where C denotes the total campaign cost, N_{SMS} is the number of participants assigned to an SMS condition, and $\hat{\tau}_k$ is the corresponding covariate-adjusted intention-to-treat estimate expressed on the 0–1 scale.

Using the pooled effect of the four active messages (0.0757) and the campaign-wide average cost per covered participant in equation (5) yields USD 0.44 per additional second-dose completion. This ratio evaluates the pooled active-message effect under the same common cost assumption used for the arm-specific comparisons.

The treatment-specific estimates reinforce the empirical ranking reported in Section 6. The ownership reminder costs an estimated USD 0.72 per additional completion, compared with USD 0.38 for the planning prompt. The corresponding ratios are USD 0.42 for the combined treatment with the 24-hour reminder and USD 0.36 for the combined treatment with the two-hour reminder. The lower ratio for the planning prompt relative to the ownership reminder reflects its larger estimated effect under the common cost assumption, rather than a difference in the cost assigned to each covered participant. These direct implementation costs are low relative to reported cost-per-vaccination benchmarks.⁴⁸

⁴⁷The planned SMS volume reflects six weekly messages for participants assigned to the placebo, ownership-reminder, and planning-prompt arms, and twelve weekly messages for participants assigned to either combined-treatment arm.

⁴⁸As a point of reference, Maldonado et al. (2026) report USD 5.53 per additional first HPV dose and USD 3.93 for the more effective norm designs. The planning-prompt ratio is approximately one tenth of the latter. Other reminders cost USD 7.50 per additional child completing age-appropriate vaccination in Guatemala

The numerical ordering among the three planning treatments should be interpreted cautiously. Although the combined two-hour treatment has the lowest ratio, the effects of the three treatments containing a planning prompt are statistically indistinguishable. Moreover, the arm-specific calculations apply the same average cost per covered participant to every treatment, even though each combined arm delivered an additional message. The calculation therefore does not allocate the higher messaging cost of the combined packages to those arms. The estimates support the conclusion that planning prompts are more cost-effective than ownership reminders under the implemented campaign, but they do not establish that a two-message package is more cost-effective than the planning prompt alone.

Table 7 also reports a ratio of USD 2.31 for the placebo message. We include this calculation for completeness, but it has no stable substantive interpretation. The placebo effect is small and statistically indistinguishable from zero, so minor changes in the estimated coefficient would generate large changes in the ratio. It should therefore not be used to compare policy alternatives.

These calculations cover the direct implementation cost of adding the SMS campaign to an existing vaccination system. They exclude vaccine procurement and administration costs, household transportation and opportunity costs, and capital investments in messaging infrastructure. The estimates therefore describe the communication campaign’s cost per additional second-dose completion, rather than the full government or social cost of vaccination.⁴⁹

Subject to these boundaries, the estimates show that time-specific planning prompts can produce sizable gains in vaccination completion at a very low direct implementation cost. This conclusion is most relevant for health authorities that already maintain vaccination

(Busso et al., 2015) and USD 7.90 per additional return visit for childhood vaccination in Nigeria (Kawakatsu et al., 2020). For social-media campaigns, Athey et al. (2023) estimate USD 5.68 per additional COVID-19 vaccination by linking experimental belief changes to observational vaccination rates. These reported-price comparisons provide context rather than a common-cost ranking: outcomes, cost coverage, and price years differ, and our estimates cover only SMS and personnel costs within existing infrastructure.

⁴⁹The experiment does not identify effects on cervical cancer incidence, mortality, quality-adjusted life years, or future medical expenditures. Extrapolating to these outcomes would require epidemiological and cost parameters outside the experimental design.

registries and have the administrative capacity to identify incomplete schedules and deliver personalized messages at scale. In such settings, the planning prompt can complement existing information and access policies without requiring a formal appointment or a change in the available choice set.

8 Concluding remarks

Completing a health investment can remain difficult even after households incur the initial cost of adoption. We study this margin in a randomized controlled trial with 5,907 parents inside and outside Bogotá whose daughters had received a first HPV vaccine dose but had not completed the schedule. The experiment compares an ownership reminder, a time-specific planning prompt, and two packages combining both components. By studying completion after adoption, we focus on households with revealed willingness to vaccinate whose constraints need not be the same as those of parents who reject or never begin vaccination.

All four active messages increased completion, although their effects differed substantially with message content. Relative to a pure-control completion rate of 8.63 percent, the ownership reminder and planning prompt increased second-dose completion by 4.58 and 8.67 percentage points, respectively. A direct test rejects equality of these effects. The three treatments containing a planning prompt were statistically indistinguishable from one another, indicating no detectable gain from adding ownership language. The negative ownership-by-planning interaction further indicates that the implemented components produced less than additive gains. The placebo estimate, by contrast, was small and statistically indistinguishable from zero.

This treatment ranking is consistent with planning and implementation frictions being especially relevant among parents at the completion margin. A parent who has accepted the first dose may still fail to select a feasible time or coordinate the return visit. A time-specific prompt can make a concrete occasion for action focal. In our setting, the recommendation improved follow-through without assigning an appointment, changing the formal default, or

restricting the choice set. The evidence does not, however, identify the psychological channel directly. We do not measure the underlying behavioral processes, and the effects may also reflect how parents interpret the messages or how well the suggested time fits their schedules.

The cost-effectiveness estimates reinforce the practical relevance of this result. The planning prompt required an estimated USD 0.38 in direct implementation costs per additional second-dose completion, compared with USD 0.72 for the ownership reminder. These amounts measure the incremental communication cost of adding the SMS campaign to an existing system, rather than the full social cost of vaccination. The low direct cost makes time-specific prompts a potentially useful complement to information and access policies when health authorities already maintain vaccination registries and can deliver personalized messages at scale.

The scope of the evidence remains specific to completion after initial vaccination. It does not establish that planning prompts can increase first-dose take-up or overcome vaccine refusal or supply constraints. Nor does the experiment compare a suggested time with a self-generated plan or a formally scheduled appointment. Future research should compare these alternatives and measure the intermediate mechanisms more directly. In particular, allowing households to select a feasible time could preserve the benefits of a concrete plan while reducing mismatch costs. Such comparisons would clarify when a planning prompt is sufficient and when a formal appointment is more effective.

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Tables

Table 1: Experimental Design and Treatment Arms

Arm	Treatment condition	SMS contact	Ownership cue	Planning prompt	Reminder timing	Observations	Share (%)
1	Pure control	No	No	No	–	985	16.7
2	Placebo control	Yes	No	No	–	985	16.7
3	Ownership reminder	Yes	Yes	No	–	983	16.6
4	Planning prompt	Yes	No	Yes	–	986	16.7
5	Planning prompt + ownership reminder	Yes	Yes	Yes	24 hours before	984	16.7
6	Planning prompt + ownership reminder	Yes	Yes	Yes	2 hours before	984	16.7
Total						5907	100.0

Notes: This table reports the randomized treatment arms in the HPV vaccination completion experiment. The sample includes parents of girls who had initiated but not completed the HPV vaccination schedule at baseline. The pure control group received no message. The placebo control group received an SMS unrelated to HPV vaccination content. The ownership cue refers to language indicating that an HPV vaccine was reserved for the daughter. The planning prompt refers to language suggesting a specific day and time for completing the vaccination schedule without assigning a formal appointment or changing the choice set. Reminder timing applies only to treatment arms combining the planning prompt with an ownership reminder.

Table 2: Descriptive Statistics and Covariate Balance

Variable	Descriptive statistics			Standardized differences relative to pure control				
	Mean	SD	Pure control mean	Placebo	Ownership	Planning prompt	Planning+Own. 24h	Planning+Own. 2h
Girl's age (years)	11.252	2.013	11.237	0.020	0.003	-0.010	0.019	0.014
Age 9–10 years	0.461	0.498	0.461	-0.002	-0.000	-0.001	0.001	-0.001
Inside Bogota	0.628	0.483	0.628	-0.002	-0.002	-0.001	-0.001	0.001
EPS Sanitas	0.147	0.354	0.144	-0.038	0.004	0.022	0.026	0.037
EPS Salud Total	0.101	0.301	0.092	0.041	0.025	0.020	0.051	0.038
EPS Famisanar	0.204	0.403	0.216	-0.035	-0.004	-0.056	-0.032	-0.057
EPS Compensar	0.184	0.387	0.180	0.008	0.040	0.013	-0.021	0.021
EPS Capital Salud	0.096	0.295	0.095	0.017	-0.042	0.023	0.021	-0.003
Other EPS	0.268	0.443	0.272	0.016	-0.024	-0.007	-0.022	-0.020
Contributory scheme	0.813	0.390	0.827	-0.068	-0.033	-0.044	-0.035	-0.040
Subsidized scheme	0.123	0.328	0.112	0.059	0.010	0.053	0.044	0.041
Uninsured	0.013	0.113	0.012	0.000	0.026	0.026	-0.009	0.000
Other health regime	0.051	0.220	0.049	0.032	0.028	-0.015	0.000	0.010
Belongs to an ethnic group	0.005	0.071	0.002	0.051	0.064	0.075	0.020	0.075
Displaced by armed conflict	0.012	0.110	0.012	-0.019	0.026	-0.019	-0.040	0.050
Colombian nationality	0.963	0.189	0.969	-0.049	-0.060	-0.028	-0.012	-0.039
Observations	5907		985	985	983	986	984	984

Notes: This table reports descriptive statistics and covariate balance for the final analysis sample. The first two columns report the full-sample mean and standard deviation. The third column reports the mean for the pure control group. The remaining columns report signed standardized differences between each listed arm and the pure control group, computed as the difference in means divided by the square root of the average of the two group-specific variances. Values close to zero indicate stronger balance. The covariates are measured before treatment assignment and come from administrative records. The pure control group received no message; the placebo-control group received an SMS unrelated to HPV vaccination content; ownership refers to language indicating that an HPV vaccine was reserved for the daughter; and planning prompt refers to language suggesting a specific day and time for completing the vaccination schedule.

Table 3: Main ITT Effects on HPV Second-Dose Completion

	(1) Strata only	(2) Covariate adjusted	(3) Double-selection LASSO	(4) OWN
Placebo control	0.0133 (0.0130)	0.0143 (0.0130)	0.0143 (0.0130)	0.0130 (0.0130)
Ownership reminder	0.0460*** (0.0139)	0.0458*** (0.0139)	0.0457*** (0.0139)	0.0466*** (0.0139)
Planning prompt	0.0862*** (0.0147)	0.0867*** (0.0147)	0.0863*** (0.0147)	0.0853*** (0.0148)
Planning prompt + ownership, 24h	0.0784*** (0.0146)	0.0794*** (0.0146)	0.0796*** (0.0146)	0.0790*** (0.0146)
Planning prompt + ownership, 2h	0.0905*** (0.0149)	0.0910*** (0.0148)	0.0909*** (0.0148)	0.0910*** (0.0148)
Pure-control mean	0.0863	0.0863	0.0863	0.0863
Observations	5907	5907	5907	5907
Strata fixed effects	Yes	Yes	Yes	Yes
Pre-treatment covariates	No	Yes	Selected	Yes
P-value: all noncontrol arms equal	0.000	0.000	0.000	0.000
P-value: planning arms equal	0.758	0.778	0.787	0.772

Notes: The dependent variable is an indicator equal to one if the girl received the follow-up HPV vaccine dose during the study period, measured in administrative vaccination records. Coefficients and standard errors are reported in the original 0–1 scale of the dependent variable; for example, an estimate of 0.0460 corresponds to a 4.60 percentage-point increase in completion. The omitted category in all columns is the pure control group. Column 1 adjusts only for randomization-strata fixed effects. Column 2 adds pre-treatment administrative covariates: EPS indicators, health-regime indicators, ethnicity, displacement status, Colombian nationality, and girl’s age. Column 3 reports double-selection LASSO estimates using the same treatment indicators and strata fixed effects as variables of interest and allowing the pre-treatment covariates to be selected controls. Column 4 reports the OWN estimator of Goldsmith-Pinkham et al. (2024), using the same pre-treatment covariates and strata; this estimator subtracts estimated contamination attributable to other treatments from the partly linear estimator. Robust standard errors are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 4: Ownership Reminders Versus Planning Prompts

	(1) Strata only	(2) Covariate adjusted	(3) Double-selection LASSO	(4) OWN
<i>Panel A. Global message effect</i>				
Any active message	0.0753*** (0.0106)	0.0757*** (0.0106)	0.0756*** (0.0106)	0.0759*** (0.0106)
<i>Panel B. Message-component decomposition</i>				
Ownership cue	0.0460*** (0.0139)	0.0458*** (0.0139)	0.0457*** (0.0139)	0.0466*** (0.0139)
Planning prompt	0.0862*** (0.0147)	0.0867*** (0.0147)	0.0863*** (0.0147)	0.0853*** (0.0148)
Ownership cue x planning prompt	-0.0539** (0.0215)	-0.0530** (0.0215)	-0.0524** (0.0215)	-0.0529** (0.0218)
2h vs 24h timing	0.0121 (0.0166)	0.0116 (0.0165)	0.0113 (0.0165)	0.0120 (0.0167)
Pure-control mean	0.0863	0.0863	0.0863	0.0863
Observations: Panel A	5907	5907	5907	5907
Observations: Panel B	5907	5907	5907	5907
Strata fixed effects	Yes	Yes	Yes	Yes
Pre-treatment covariates	No	Yes	Selected	Yes
P-value: ownership = planning	0.011	0.010	0.010	0.015
P-value: interaction = 0	0.012	0.014	0.015	0.015
P-value: 2h = 24h	0.465	0.484	0.493	0.472

Notes: The dependent variable indicates completion of the follow-up HPV vaccine dose during the study period, measured in administrative vaccination records. Coefficients and standard errors are reported on the 0–1 scale. The pure-control arm is the reference category; the placebo arm is retained as a separate category. Panel A pools the four active messages. Panel B reports the ownership and planning effects, their interaction, and the contrast between reminders sent two and 24 hours before the suggested time. Column 1 includes randomization-strata fixed effects. Column 2 adds pre-treatment EPS indicators, health-regime indicators, ethnicity, displacement status, Colombian nationality, and girl’s age. Column 3 reports double-selection LASSO estimates, retaining treatment indicators and strata fixed effects and selecting among the pre-treatment covariates. Column 4 uses the OWN estimator of Goldsmith-Pinkham et al. (2024), with the same covariates and strata. In Panel B, columns 1–3 estimate a component model; column 4 reports the corresponding contrasts of arm-specific OWN effects. The interaction is the effect of the combined 24-hour arm minus the ownership-only and planning-only effects; the timing contrast is the difference between the combined two-hour and 24-hour arms. Standard errors and equality tests for these contrasts use the joint covariance matrix of the arm-specific estimates. Robust standard errors are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 5: Multiple Inference and Robust Inference

	Estimate	Robust SE	Robust p	BH q	RI p
Placebo control	0.0143	(0.0130)	0.274	0.274	0.285
Ownership reminder	0.0458***	(0.0139)	0.001	0.001	0.001
Planning prompt	0.0867***	(0.0147)	< 0.001	< 0.001	< 0.001
Planning prompt + ownership, 24h	0.0794***	(0.0146)	< 0.001	< 0.001	< 0.001
Planning prompt + ownership, 2h	0.0910***	(0.0148)	< 0.001	< 0.001	< 0.001
Pure-control mean	0.0863				
Observations	5907				
Randomization strata fixed effects	Yes				
Pre-treatment covariates	Yes				
RI replications	10000				

Notes: The dependent variable is an indicator equal to one if the girl received the follow-up HPV vaccine dose during the study period, measured in administrative vaccination records. Estimates come from the covariate-adjusted linear probability model in Table 3; the omitted category is the pure control group. Coefficients and standard errors are reported in the original 0–1 scale of the dependent variable. Robust p -values use Eicker-Huber-White standard errors. BH q -values apply the Benjamini-Hochberg false-discovery-rate adjustment to the five treatment-arm contrasts reported in the table. RI p -values are two-sided stratified randomization-inference p -values based on the absolute robust t -statistic and 10000 permutations of the treatment assignment within randomization strata. Treatment was assigned at the parent-household level; because nearly all participating households contribute only one eligible girl to the final analysis sample, household clustering is not a meaningful additional correction. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 6: Pre-Specified Heterogeneous Effects

	Age 9–10	Inside Bogota	Subsidized or uninsured	Colombian national	Displaced
<i>Panel A. Pooled message effect</i>					
Any message, subgroup = 0	0.0346*** (0.0129)	0.0330*** (0.0115)	0.0725*** (0.0116)	0.0841** (0.0415)	0.0747*** (0.0107)
Any message, subgroup = 1	0.1243*** (0.0172)	0.1013*** (0.0154)	0.0997*** (0.0251)	0.0757*** (0.0109)	0.1797*** (0.0548)
Difference: subgroup 1 - subgroup 0	0.0897*** (0.0215)	0.0683*** (0.0193)	0.0271 (0.0277)	-0.0084 (0.0429)	0.1050* (0.0557)
<i>Panel B. Arm-specific heterogeneity terms</i>					
Ownership reminder x subgroup	0.0641** (0.0284)	0.0245 (0.0257)	0.0744* (0.0411)	-0.0059 (0.0532)	0.1651 (0.1086)
Planning prompt x subgroup	0.1154*** (0.0299)	0.0956*** (0.0264)	0.0078 (0.0383)	-0.0076 (0.0636)	0.0592 (0.1101)
Planning prompt + ownership, 24h x subgroup	0.1085*** (0.0298)	0.0638** (0.0268)	0.0238 (0.0403)	0.0175 (0.0546)	0.0663 (0.1149)
Planning prompt + ownership, 2h x subgroup	0.0707** (0.0302)	0.0894*** (0.0269)	0.0031 (0.0400)	-0.0388 (0.0655)	0.0993 (0.0872)
P-value: arm-specific interactions jointly zero	< 0.001	< 0.001	0.456	0.951	0.427
Pure-control mean, subgroup = 0	0.0734	0.0328	0.0915	0.0323	0.0874
Pure-control mean, subgroup = 1	0.1013	0.1179	0.0492	0.0881	0.0000
Subgroup observations	2,268	3,092	662	4,742	63
Regression observations	4,922	4,922	4,922	4,922	4,922
Strata fixed effects	Yes	Yes	Yes	Yes	Yes
Pre-treatment covariates	Yes	Yes	Yes	Yes	Yes

Notes: The dependent variable is an indicator equal to one if the girl completed the HPV second dose during the study period, measured in administrative vaccination records. The estimation sample excludes the placebo-control arm and compares the pure control group with the four active active-message arms. Panel A reports covariate-adjusted effects of receiving any of the four active messages separately for observations with subgroup indicator equal to zero and one, plus the interaction difference. Panel B reports treatment-arm-specific interaction terms between each active treatment arm and the subgroup indicator. All specifications are linear probability models with randomization-strata fixed effects and the same pre-treatment administrative covariates used in Table 3. The age and Bogota subgroup main effects are absorbed by the randomization-strata fixed effects when collinear with the strata, but their treatment interactions are identified. Heterogeneity by Colombian nationality and displacement status should be interpreted cautiously because the corresponding reference or subgroup cells are small. Robust standard errors are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

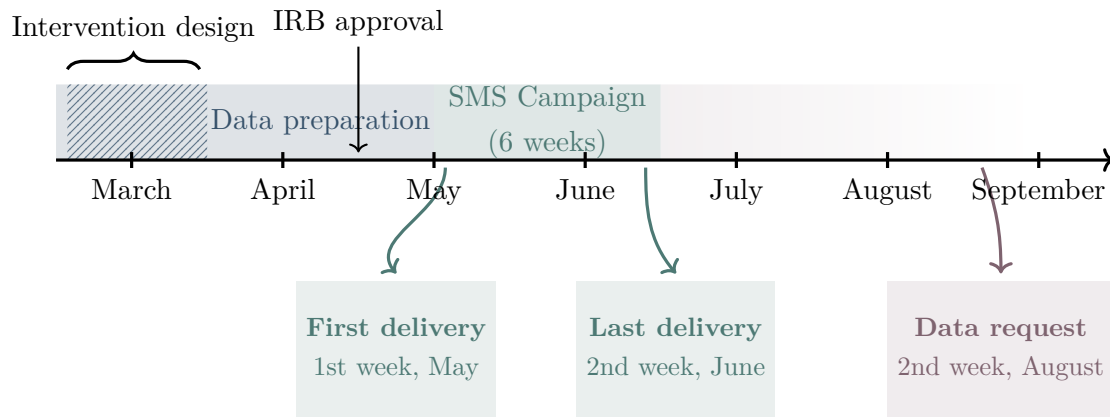
Table 7: Cost-Effectiveness

<i>Panel A. Costs</i>	
Item	Implementation costs (2022 USD)
Labor costs	88.89
SMS costs	73.49
Total costs	162.38
Participants covered	4,922
Total cost per participant	0.03
Planned SMS	41,340
<i>Panel B. Cost-effectiveness</i>	
Item	Estimate
Average impact of any active message	0.0757
Cost per additional vaccination	0.44
Impact of placebo message	0.0143
Cost per additional vaccination	2.31
Impact of ownership reminder	0.0458
Cost per additional vaccination	0.72
Impact of planning prompt only	0.0867
Cost per additional vaccination	0.38
Impact of planning prompt + ownership, 24h	0.0794
Cost per additional vaccination	0.42
Impact of planning prompt + ownership, 2h	0.0910
Cost per additional vaccination	0.36

Notes: Panel A reports implementation costs from the government perspective in 2022 USD. A participant is covered if assigned to any SMS arm, including the placebo and the four active messages; the pure control group receives no message. Panel B applies the same campaign-wide average cost per covered participant to each covariate-adjusted ITT effect on second-dose HPV vaccination. The numerator averages costs across all SMS arms, including the placebo; it does not allocate costs separately by treatment. The pooled active-message effect combines the ownership reminder, planning prompt, planning prompt plus ownership reminder at 24 hours, and planning prompt plus ownership reminder at 2 hours. The treatment-specific rows report the corresponding arm-specific ITT effects. All treatment effects are estimated relative to the pure control group with the same pre-treatment covariates and randomization-strata fixed effects as Table 3. Each SMS costs 8 COP and message programming/delivery required 10 labor hours at 40,000 COP per hour. The planned SMS volume is 41,340: six weekly SMS for the placebo, ownership-reminder, and planning-prompt arms, and twelve weekly SMS for each combined arm. USD values use 4,500 COP per USD. The exercise excludes vaccine costs, parental opportunity and transport costs, and capital investments in messaging infrastructure.

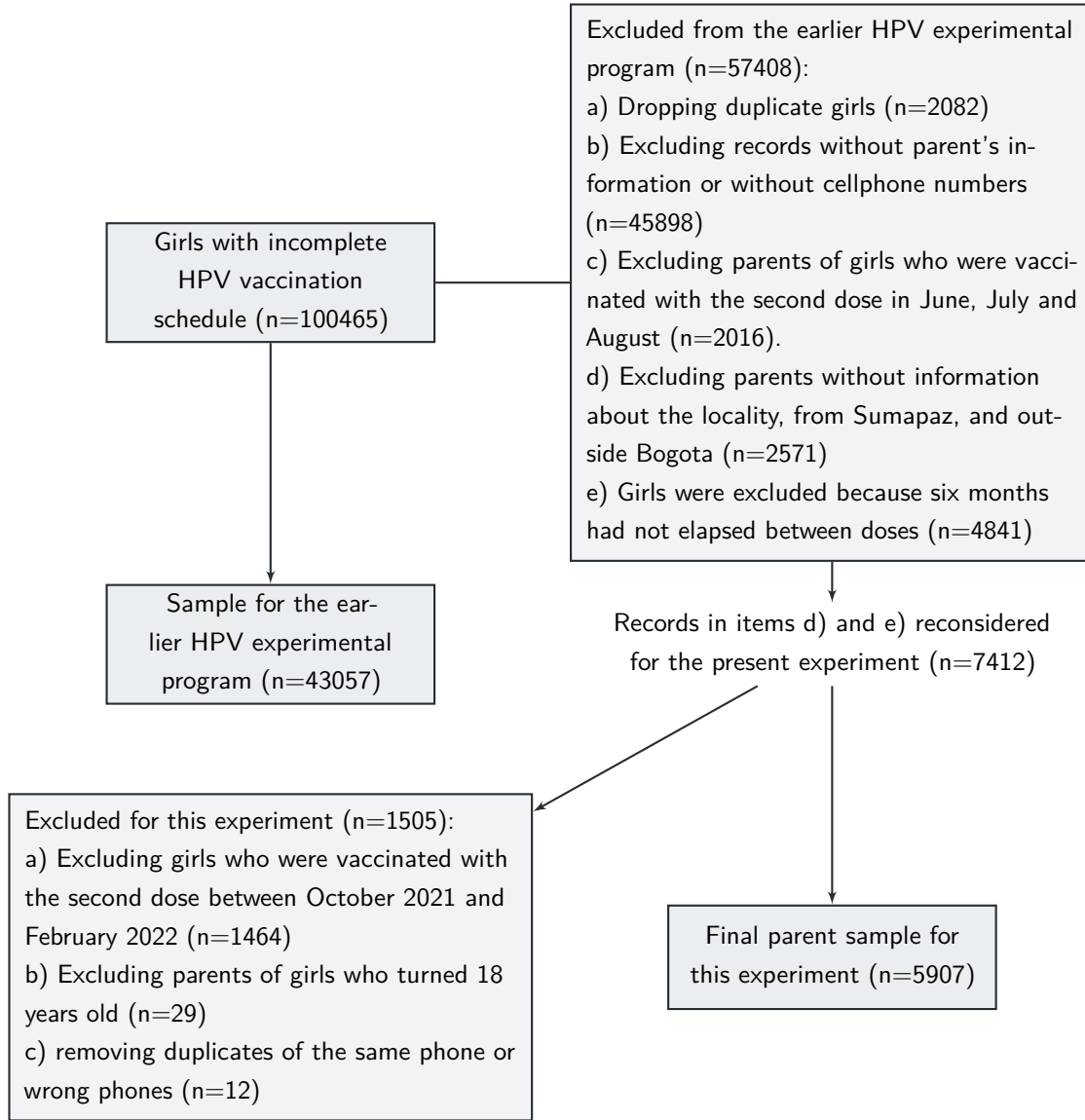
Figures

Figure 1: Experiment Timeline



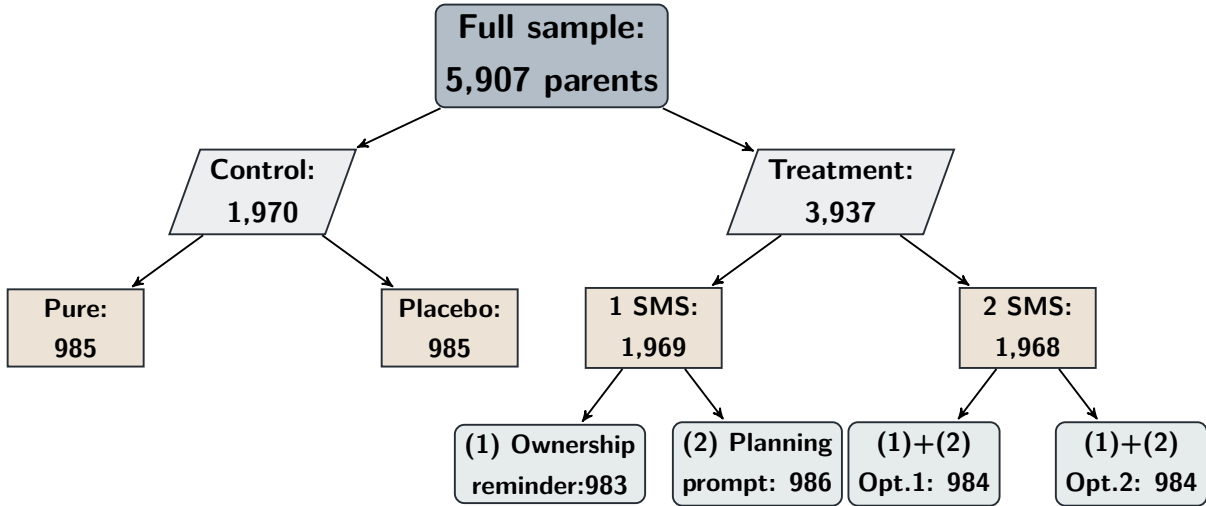
Notes: The figure summarizes the implementation timeline for the 2022 message experiment. The design and data-preparation phase preceded the six-week SMS campaign. The first SMS round was delivered on Wednesday, May 4, 2022, and the last round was delivered on Saturday, June 11, 2022. Outcome data were requested from administrative vaccination records in the second week of August 2022, allowing vaccination completion to be measured after the campaign window.

Figure 2: Sample construction for this experiment



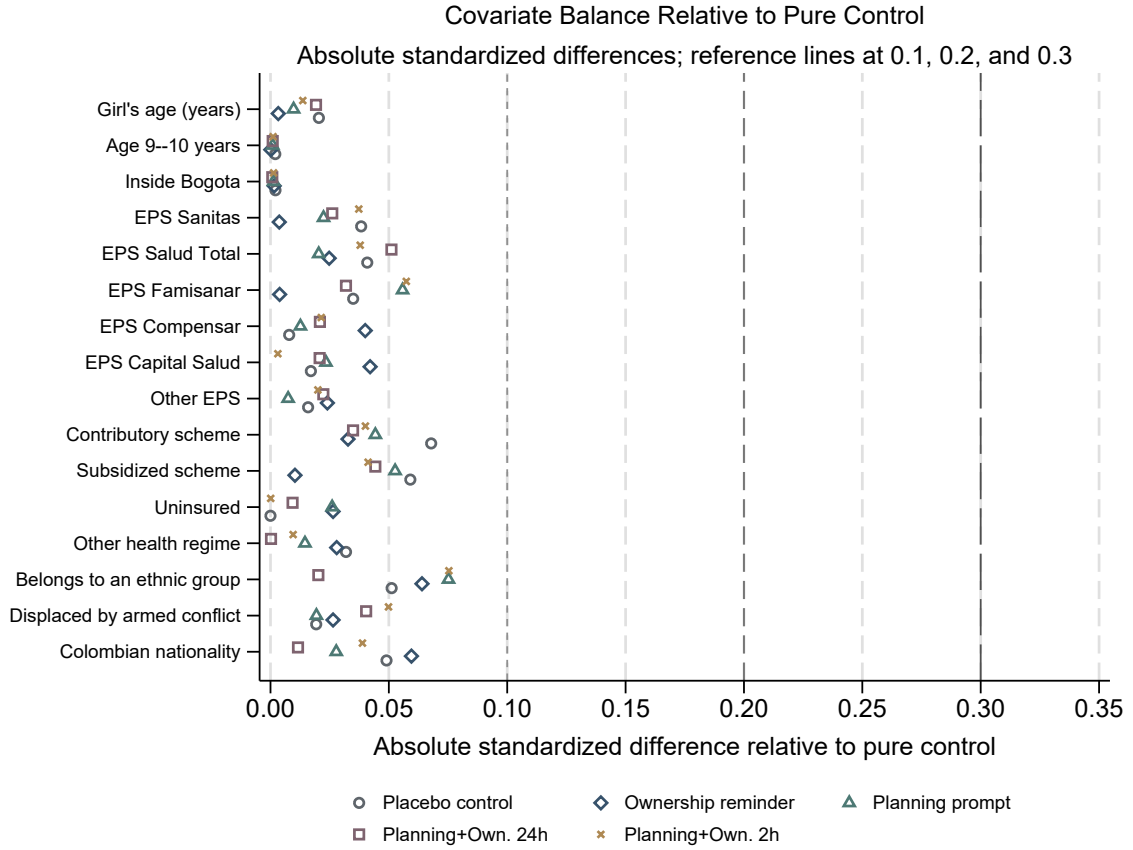
Notes: The figure traces the construction of the experimental sample from Health Secretariat records of girls with incomplete HPV vaccination schedules. An earlier program of HPV vaccination experiments used 43,057 records from this incomplete-schedule frame. Of the 57,408 excluded records, 7,412 were reconsidered for the present study: 2,571 had been excluded because of geographic restrictions or missing locality information and 4,841 because the six-month interval between doses had not elapsed. Updating eligibility and contact information removed another 1,505 records, leaving 5,907 randomized parent records, each linked to an eligible daughter.

Figure 3: Experimental design for the experiment



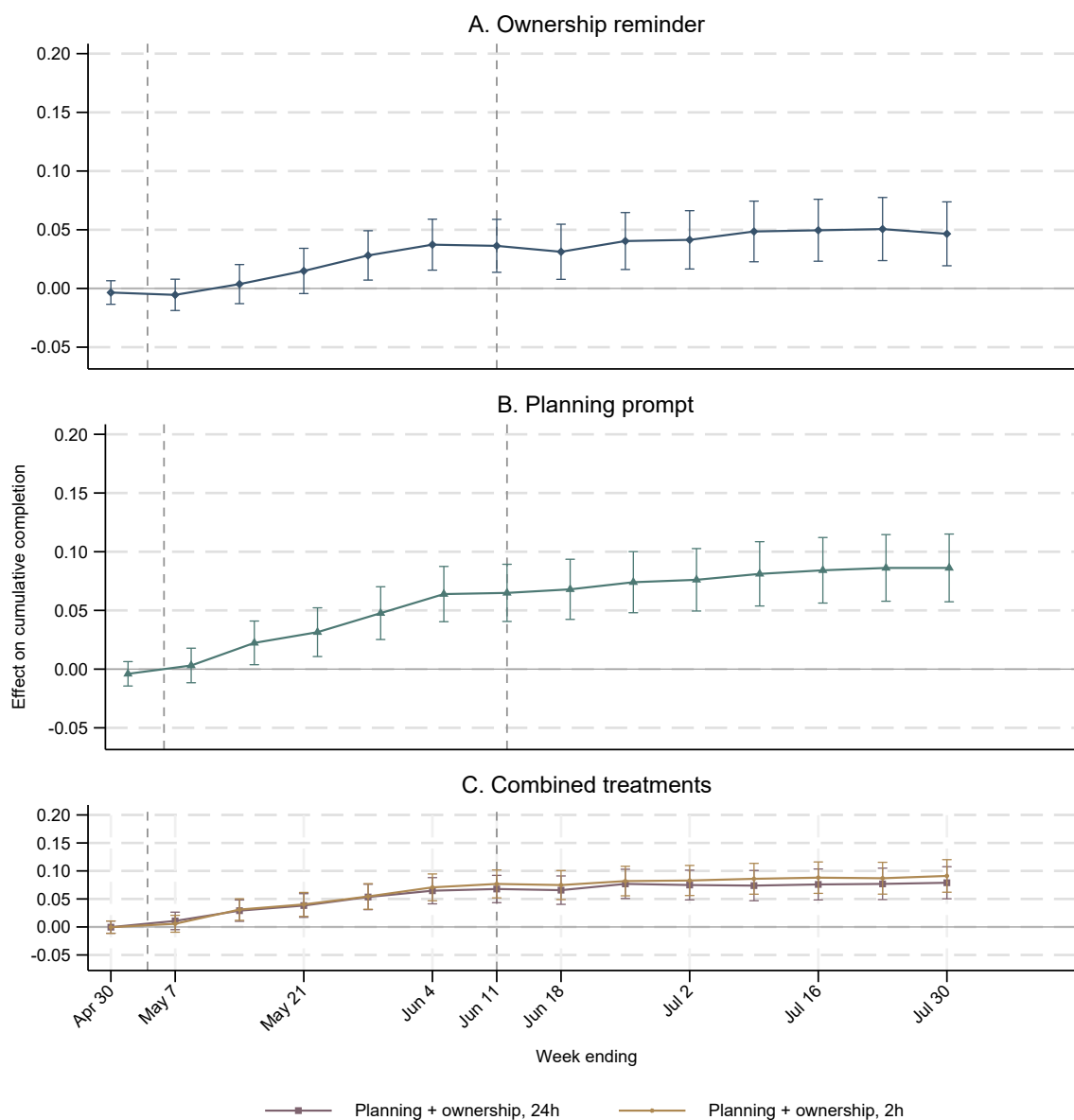
Notes: The figure reports the randomized assignment structure for the final experimental sample of 5,907 parents. The control group contains a pure control arm with no SMS and a placebo-control arm with non-behavioral SMS content. The active-treatment group contains two one-SMS arms, ownership reminder and planning prompt, and two two-SMS arms combining the planning prompt with an ownership reminder sent either 24 hours or 2 hours before the suggested vaccination time. The messages did not assign a formal appointment. Cell counts report the number of parents assigned to each arm after randomization.

Figure 4: Covariate Balance Plot Relative to Pure Control



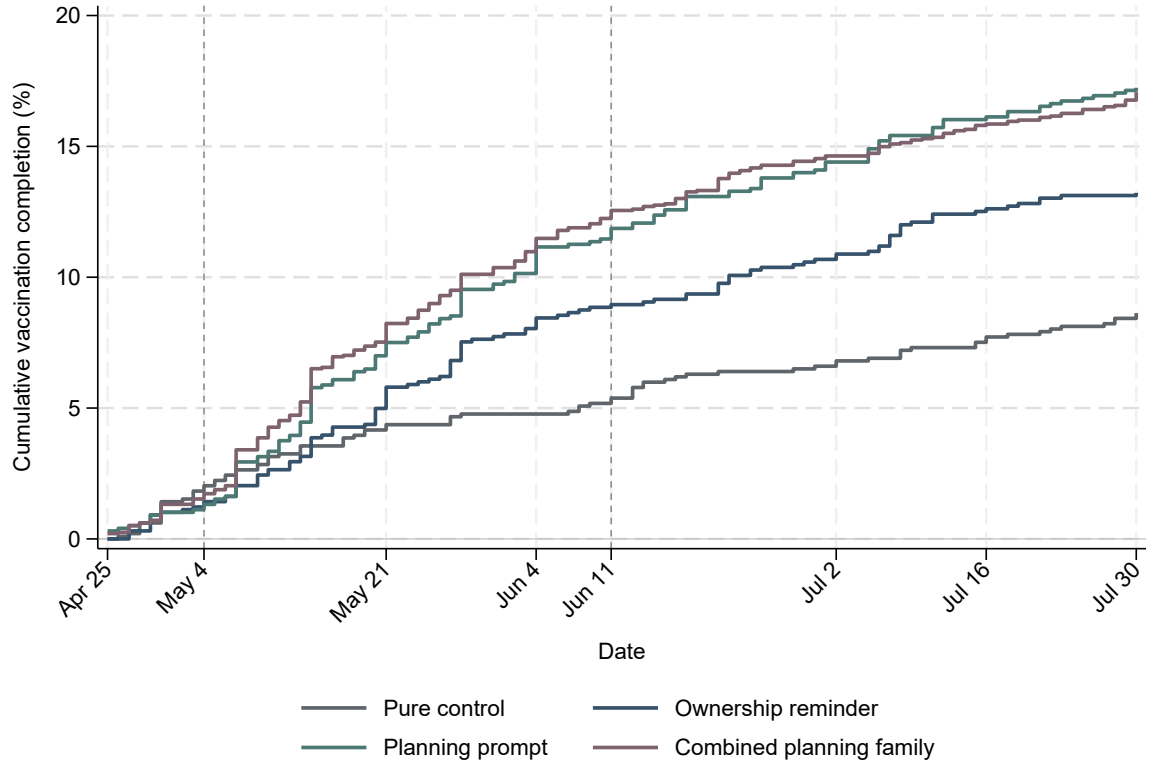
Notes: The figure reports absolute standardized differences in baseline covariates between each non-pure-control arm and the pure control group. Standardized differences are computed as the difference in group means divided by the square root of the average of the two group-specific variances. Vertical reference lines mark conventional thresholds of 0.1, 0.2, and 0.3 in absolute standardized-difference units. Values closer to zero indicate stronger covariate balance. Covariates are measured before treatment assignment and come from administrative records.

Figure 5: Dynamic Treatment Effects



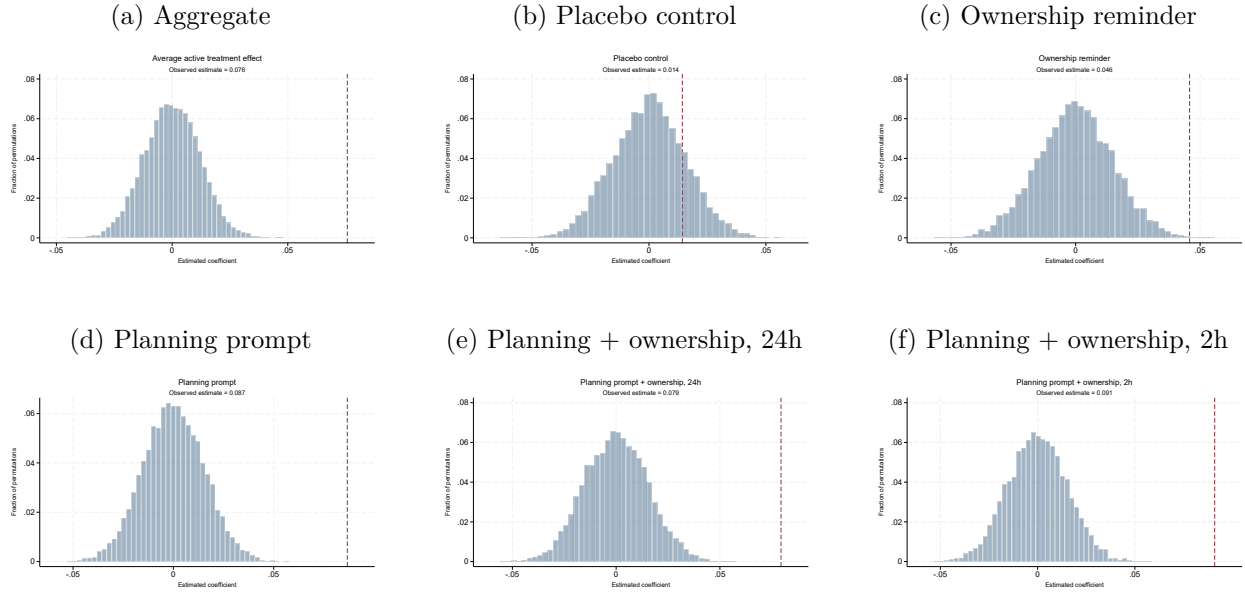
Notes: The figure reports weekly treatment effects on cumulative HPV second-dose completion relative to the pure control group. Panel A reports the ownership reminder arm; Panel B reports the planning-prompt arm; Panel C reports the two combined planning-prompt plus ownership-reminder arms. Outcomes are cumulative indicators equal to one if the girl had completed the second dose by the end of each calendar week. Estimates come from linear probability models in the stacked girl-week panel and include week fixed effects, randomization-strata fixed effects, and the same baseline covariates used in the main ITT specification. Vertical dashed lines mark the first SMS delivery on May 4, 2022, and the last SMS delivery on June 11, 2022. Error bars are 95 percent confidence intervals based on standard errors clustered at the girl level.

Figure 6: Kaplan-Meier Vaccination Completion



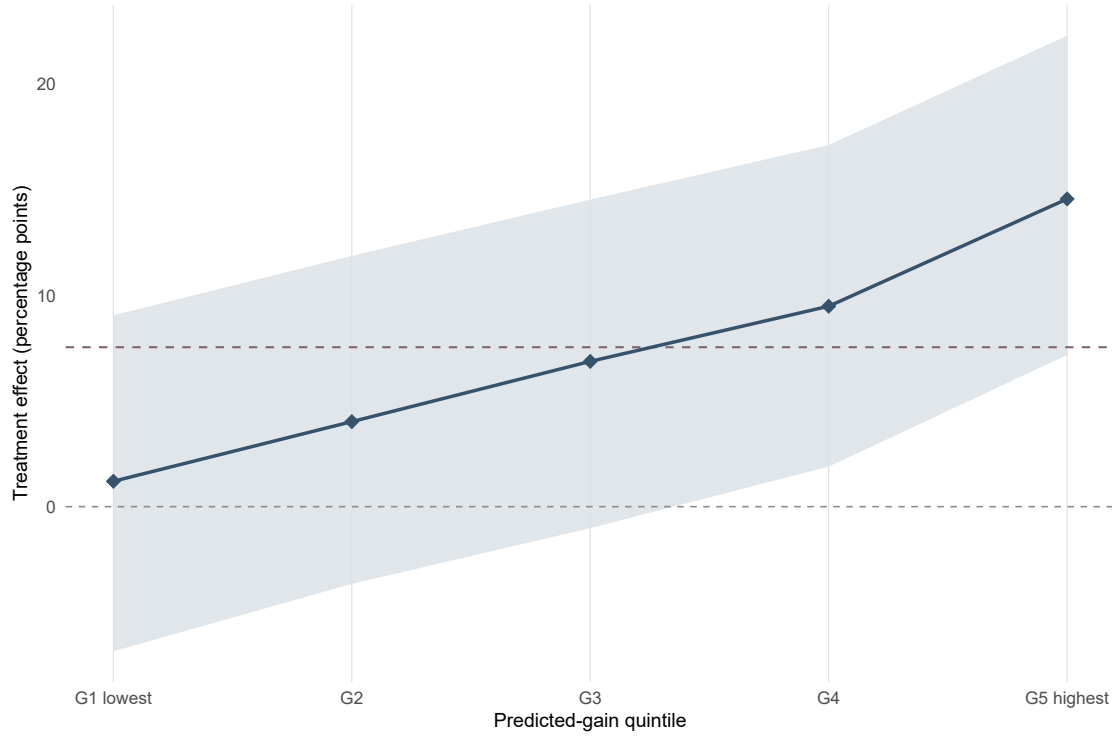
Notes: The figure reports Kaplan-Meier-style cumulative completion curves for HPV second-dose vaccination during the administrative follow-up window. The pure control arm received no SMS. The ownership-reminder curve corresponds to the ownership-only treatment arm; the planning-prompt curve corresponds to the planning-only treatment arm; and the combined planning family pools the two treatment arms that combined planning-prompt language with an ownership reminder. The time axis begins on April 25, 2022, the first observed vaccination date in the follow-up data, and ends on July 30, 2022. Vertical dashed lines mark the first SMS delivery on May 4, 2022, and the last SMS delivery on June 11, 2022. Because there is only administrative censoring at the end of follow-up, the plotted curves are equivalent to cumulative completion rates by date.

Figure 7: Randomization-Inference Permutation Distributions



Notes: Each panel plots the permutation distribution of the covariate-adjusted coefficient from 10000 treatment reassignments within randomization strata. The vertical line marks the observed estimate in the final analysis sample. The aggregate panel reports the equally weighted average of the four active-message treatment-arm coefficients relative to pure control; this is numerically equivalent to the pooled active-message effect up to the small imbalance in treatment-arm counts.

Figure 8: GenericML Group Average Treatment Effects



Notes: The figure reports group average treatment effects (GATES) estimated using the framework of Chernozhukov et al. (2025). The outcome is completion of the second HPV vaccine dose. The analysis compares assignment to any of the four active messages with the pure-control arm and excludes the placebo, yielding a sample of 4,922 observations. Groups are quintiles ranked from the lowest (G1) to the highest (G5) predicted treatment gains. For each sample split, one half is used to construct the predicted-gain score and the other to estimate group effects; estimates are aggregated across 100 splits using medians. The shaded region shows 90% confidence intervals at each quintile. The upper dashed horizontal line reports the average treatment effect from the best linear predictor; the dashed line at zero marks no effect. Effects are expressed in percentage points.

Online Appendix to Accompany

**“Planning frictions and the incomplete take-up
of health investments: The case of HPV
vaccination”**

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This version: August 14, 2026

Not for Publication

A Conceptual framework: full derivation and proofs

This appendix derives the framework summarized in Section 2. We model how ownership reminders and time-specific planning prompts affect the decision to complete the HPV vaccination schedule, identify the channels each message may activate, and establish the assumptions needed to interpret the experimental comparisons.

A.1 Decision problem

A parent decides whether to complete her daughter’s HPV vaccination schedule. Let $x_i \in \{0, 1\}$ denote the completion decision, where $x_i = 1$ if the daughter receives the second dose and $x_i = 0$ otherwise. The net value of completion before accounting for reference-dependent utility or message effects is

$$\theta_i = B_i - C_i, \tag{A.1}$$

where B_i is the parent’s perceived value of completing the HPV schedule and C_i is the full cost of vaccination. It includes transportation, time, and hassle costs, uncertainty about when to go, and the cognitive cost of translating an intention into action.

Let $t \in \mathcal{T}$ denote the experimental condition, where

$$\mathcal{T} = \{C, P, O, D, OD\}.$$

Here, C denotes the pure control condition, P the placebo message, O the ownership reminder, D the time-specific planning prompt, and OD a combined treatment.

Treatments may affect completion through salience, reference points, and implementation costs. Let $s_i(t)$ capture the salience effect of receiving a message from the health authority, including institutional contact, personalization, and attention to vaccination. We allow salience to vary across message conditions; equality across arms is an additional assumption used below.¹

¹Karlan et al. (2016) model how reminders can mitigate undersaving by directing attention to future

Ownership language may strengthen an entitlement reference point, $e(t)$, which captures the extent to which the parent perceives the dose as assigned to her daughter.² A planning prompt may strengthen a plan reference point, $p(t)$, by making a specific day and time the expected moment for action.³

A planning prompt may also reduce the cost of deciding when and how to act. An inconvenient suggested time may instead create mismatch costs if it disrupts an alternative plan.⁴ We write this net implementation effect as $\omega_i a(t)$, where $a(t) = 1$ for treatments with a suggested day and time and $a(t) = 0$ otherwise. The parameter ω_i can be positive, zero, or negative.

Let $\kappa_i(t) \geq 0$ denote a message-burden cost that lowers the payoff from completion through confusion, fatigue, or complexity from combining messages. We set this cost to zero outside the combined treatments as a simplifying restriction.⁵

The parent has reference-dependent preferences over the entitlement and plan dimensions. The binary outcome records completion rather than adherence to the suggested time, so we abstract from deviations from that time. Let $L_i(e, p)$ denote the loss from failing to act when

expenses. We draw on this attention channel and represent it through an additive term, separately from reference-dependent utility and implementation costs.

²The endowment-effect and psychological-ownership literatures motivate the role of perceived possession in valuation (Thaler, 1980; Kahneman et al., 1990; Pierce et al., 2001). Vaccination experiments provide evidence that reservation messages can increase uptake (Milkman et al., 2021; Dai et al., 2021). Our interpretation requires the parent to adopt the perceived allocation as a benchmark; it does not require physical possession of the dose.

³Koch and Nafziger (2011) model self-chosen goals as reference points that make shortfalls psychologically costly. We apply this logic to a suggested vaccination time if the parent adopts it as a benchmark. The implementation-intentions literature examines how concrete plans help translate intentions into behavior (Gollwitzer, 1999; Gollwitzer and Sheeran, 2006), including vaccination (Milkman et al., 2011).

⁴Reis (2006) models the resource costs of forming and updating plans. A suggested vaccination time may save some of this effort. Because parents remain free to attend at another time, mismatch costs require a response that disrupts existing arrangements; an inconvenient suggestion that is simply ignored need not raise costs.

⁵This term affects the relative payoff from completion. A nuisance from receiving an SMS that affects completion and noncompletion equally would cancel from the utility comparison and leave the action threshold unchanged.

the entitlement and plan reference points are e and p . We assume

$$L_i(0, 0) = 0, \quad L_{i,e}(e, p) \geq 0, \quad L_{i,p}(e, p) \geq 0. \quad (\text{A.2})$$

The parameter $\lambda_i > 0$ captures the weight placed on reference-dependent losses.⁶

The utility from choosing x_i under treatment t is

$$U_i(x_i; t) = x_i [\theta_i + s_i(t) + \omega_i a(t) - \kappa_i(t)] - (1 - x_i) \lambda_i L_i(e(t), p(t)). \quad (\text{A.3})$$

Completion yields the net vaccination payoff, adjusted by salience, implementation effects, and message burden. Noncompletion avoids the action cost but entails a reference-dependent loss when entitlement or plan reference points are present.

The parent completes the schedule if $U_i(1; t) \geq U_i(0; t)$. Using (A.3), this condition is equivalent to

$$\theta_i + s_i(t) + \omega_i a(t) - \kappa_i(t) + \lambda_i L_i(e(t), p(t)) \geq 0. \quad (\text{A.4})$$

Define the behavioral shift generated by treatment t as

$$\Gamma_i(t) = s_i(t) + \omega_i a(t) - \kappa_i(t) + \lambda_i L_i(e(t), p(t)). \quad (\text{A.5})$$

The completion rule can then be written as

$$x_i(t) = 1 \quad \text{if and only if} \quad \theta_i + \Gamma_i(t) \geq 0. \quad (\text{A.6})$$

⁶The loss term draws on prospect theory and subsequent models of reference-dependent preferences (Kahneman and Tversky, 1979; Tversky and Kahneman, 1991; Kőszegi and Rabin, 2006). The normalization assigns no reference loss to noncompletion when both reference points are zero; the nonnegative partial derivatives imply that strengthening either reference cannot reduce that loss. We specify reference points as functions of the assigned message, without imposing consistency between expectations and choices as in Kőszegi and Rabin (2006).

A.2 Treatment mapping

The experimental arms can be mapped into the model as follows:

$$\begin{aligned}
C : \quad & s_i(C) = 0, \quad a(C) = 0, \quad \kappa_i(C) = 0, \quad e(C) = e_0, \quad p(C) = p_0, \\
P : \quad & s_i(P) > 0, \quad a(P) = 0, \quad \kappa_i(P) = 0, \quad e(P) = e_0, \quad p(P) = p_0, \\
O : \quad & s_i(O) > 0, \quad a(O) = 0, \quad \kappa_i(O) = 0, \quad e(O) = e_0 + \delta_E, \quad p(O) = p_0, \\
D : \quad & s_i(D) > 0, \quad a(D) = 1, \quad \kappa_i(D) = 0, \quad e(D) = e_0, \quad p(D) = p_0 + \delta_P, \\
OD : \quad & s_i(OD) > 0, \quad a(OD) = 1, \quad \kappa_i(OD) \geq 0, \quad e(OD) = e_0 + \delta_E, \quad p(OD) = p_0 + \delta_P.
\end{aligned} \tag{A.7}$$

The placebo message captures the common features of personalized contact with the Health Secretariat while leaving HPV-specific reference points unchanged. Ownership language raises perceived entitlement by $\delta_E \geq 0$, while the planning prompt strengthens the plan reference point by $\delta_P \geq 0$ and affects implementation costs through ω_i . The combined treatment shifts both reference points and may impose an additional burden, $\kappa_i(OD)$.

The loss function allows entitlement and plan reference points to be complements, substitutes, or additively separable. The effect of combining messages therefore depends in part on whether their reference-point channels reinforce each other or overlap.

A.3 Propositions and proofs

Proposition A1. Threshold rule and marginal parents. A parent completes the vaccination schedule under treatment t if and only if

$$\theta_i \geq -\Gamma_i(t), \tag{A.8}$$

where $\Gamma_i(t)$ is defined in (A.5). For any comparison of two conditions, completion changes only for parents whose θ_i lies between the corresponding action thresholds.

Proof. From (A.3),

$$U_i(1; t) = \theta_i + s_i(t) + \omega_i a(t) - \kappa_i(t)$$

and

$$U_i(0; t) = -\lambda_i L_i(e(t), p(t)).$$

The parent completes the schedule if $U_i(1; t) \geq U_i(0; t)$, which is equivalent to

$$\theta_i + s_i(t) + \omega_i a(t) - \kappa_i(t) + \lambda_i L_i(e(t), p(t)) \geq 0.$$

Using the definition of $\Gamma_i(t)$, this becomes

$$\theta_i + \Gamma_i(t) \geq 0,$$

or, equivalently,

$$\theta_i \geq -\Gamma_i(t).$$

Parents above both thresholds complete under either condition, while those below both thresholds complete under neither. Treatment effects therefore arise among parents whose net valuation lies between the two thresholds. $\square$

Proposition A2. Ownership reminders increase completion if they create entitlement. Suppose the ownership reminder increases the entitlement reference point, so that $e(O) > e(P)$, while leaving the plan reference point and the planning component unchanged. Assume also that generic salience is the same in the placebo and ownership arms, $s_i(O) = s_i(P)$. If $L_{i,e}(e, p) > 0$, then the ownership reminder weakly increases the behavioral incentive to complete the schedule relative to the placebo message. The effect on completion is strictly positive if a positive mass of parents satisfies

$$-\Gamma_i(O) \leq \theta_i < -\Gamma_i(P). \tag{A.9}$$

Proof. Using (A.5), the difference in behavioral shifts between the ownership reminder

and the placebo message is

$$\Gamma_i(O) - \Gamma_i(P) = \lambda_i [L_i(e_0 + \delta_E, p_0) - L_i(e_0, p_0)],$$

where we use $s_i(O) = s_i(P)$, $a(O) = a(P) = 0$, and $\kappa_i(O) = \kappa_i(P) = 0$. Since $\delta_E \geq 0$, $\lambda_i > 0$, and $L_{i,e}(e, p) \geq 0$, this difference is weakly positive. If $L_{i,e}(e, p) > 0$ over the relevant range and $\delta_E > 0$, it is strictly positive.

By Proposition A1, the ownership reminder lowers the action threshold from $-\Gamma_i(P)$ to $-\Gamma_i(O)$. Since $\Gamma_i(O) \geq \Gamma_i(P)$, we have $-\Gamma_i(O) \leq -\Gamma_i(P)$. Parents with

$$-\Gamma_i(O) \leq \theta_i < -\Gamma_i(P)$$

complete under the ownership reminder but not under the placebo message. If there is positive mass of such parents, the treatment effect is strictly positive. $\square$

Proposition A3. Planning prompts increase completion if planning benefits and plan-reference effects dominate mismatch costs. Suppose the time-specific planning prompt creates a plan reference point, so that $p(D) > p(P)$, and affects implementation costs through ω_i . Assume also that generic salience is the same in the placebo and planning-prompt arms, $s_i(D) = s_i(P)$. Relative to the placebo message, the planning prompt weakly increases the behavioral incentive to complete the schedule if

$$\omega_i + \lambda_i [L_i(e_0, p_0 + \delta_P) - L_i(e_0, p_0)] \geq 0. \tag{A.10}$$

If this condition holds for all parents, completion weakly increases in the population. The increase is strict if a positive mass of parents crosses the completion threshold.

Proof. Using (A.5), the difference in behavioral shifts between the planning prompt and

the placebo message is

$$\Gamma_i(D) - \Gamma_i(P) = \omega_i + \lambda_i [L_i(e_0, p_0 + \delta_P) - L_i(e_0, p_0)],$$

where we use $s_i(D) = s_i(P)$, $a(D) = 1$, $a(P) = 0$, and $\kappa_i(D) = \kappa_i(P) = 0$. The first term, ω_i , captures the net implementation effect of the suggested day and time: planning benefits net of mismatch costs. The second term captures the reference-dependent loss from failing to follow the plan reference point.

If this expression is weakly positive, then $\Gamma_i(D) \geq \Gamma_i(P)$, so the planning prompt weakly lowers the action threshold. If the inequality is strict for a positive mass of parents satisfying

$$-\Gamma_i(D) \leq \theta_i < -\Gamma_i(P),$$

then those parents complete under the planning prompt but not under the placebo message. When the incentive shift is nonnegative for all parents, these switches imply a strictly positive aggregate effect. $\square$

Proposition A4. The ranking of ownership reminders and planning prompts is theoretically ambiguous. Under equal salience across the placebo, ownership, and planning arms, the content-specific behavioral shifts relative to placebo are

$$\Delta_i^O = \lambda_i [L_i(e_0 + \delta_E, p_0) - L_i(e_0, p_0)], \quad (\text{A.11})$$

and

$$\Delta_i^D = \omega_i + \lambda_i [L_i(e_0, p_0 + \delta_P) - L_i(e_0, p_0)]. \quad (\text{A.12})$$

The model does not determine whether $\Delta_i^O > \Delta_i^D$ or $\Delta_i^D > \Delta_i^O$. Accordingly, the treatment effect of the ownership reminder can be larger than, smaller than, or similar to the treatment effect of the planning prompt.

Proof. The ownership reminder affects completion through the entitlement reference point, while the planning prompt affects completion through both the plan reference point and the net implementation term ω_i . The model imposes no restriction linking δ_E , δ_P , λ_i , the marginal effects of $L_i(e, p)$, and ω_i . Therefore, there are admissible parameter values under which

$$\Delta_i^O > \Delta_i^D$$

and admissible parameter values under which

$$\Delta_i^D > \Delta_i^O.$$

For example, if entitlement losses are large and planning benefits are small or mismatch costs are large, then $\Delta_i^O > \Delta_i^D$. Conversely, if planning benefits and plan-reference losses are large relative to entitlement losses, then $\Delta_i^D > \Delta_i^O$. Hence the ranking is theoretically ambiguous.

□

Proposition A5. Reference-point interactions and message burden determine whether the combined incentive shift is additive. Under equal salience across message arms, the content-specific behavioral shift of the combined treatment relative to placebo is

$$\Delta_i^{OD} = \omega_i - \kappa_i(OD) + \lambda_i [L_i(e_0 + \delta_E, p_0 + \delta_P) - L_i(e_0, p_0)]. \quad (\text{A.13})$$

Define the interaction between the entitlement and plan reference points as

$$\begin{aligned} \mathcal{I}_i = & L_i(e_0 + \delta_E, p_0 + \delta_P) - L_i(e_0 + \delta_E, p_0) \\ & - L_i(e_0, p_0 + \delta_P) + L_i(e_0, p_0). \end{aligned} \quad (\text{A.14})$$

For the specified reference-point shifts, $\mathcal{I}_i > 0$ indicates complementarity, $\mathcal{I}_i = 0$ additivity, and $\mathcal{I}_i < 0$ substitution or overlap. Relative to the sum of the individual content-specific

shifts,

$$\Delta_i^{OD} - (\Delta_i^O + \Delta_i^D) = \lambda_i \mathcal{I}_i - \kappa_i(OD). \quad (\text{A.15})$$

Proof. Using the definition of $\Gamma_i(t)$, and assuming equal generic salience across message arms, the combined treatment has the content-specific shift

$$\Delta_i^{OD} = \omega_i - \kappa_i(OD) + \lambda_i [L_i(e_0 + \delta_E, p_0 + \delta_P) - L_i(e_0, p_0)].$$

The sum of the individual content-specific shifts is

$$\Delta_i^O + \Delta_i^D = \omega_i + \lambda_i [L_i(e_0 + \delta_E, p_0) - L_i(e_0, p_0)] + \lambda_i [L_i(e_0, p_0 + \delta_P) - L_i(e_0, p_0)].$$

Subtracting this expression from Δ_i^{OD} gives

$$\begin{aligned} \Delta_i^{OD} - (\Delta_i^O + \Delta_i^D) &= -\kappa_i(OD) + \lambda_i \left[L_i(e_0 + \delta_E, p_0 + \delta_P) - L_i(e_0 + \delta_E, p_0) \right. \\ &\quad \left. - L_i(e_0, p_0 + \delta_P) + L_i(e_0, p_0) \right] \\ &= \lambda_i \mathcal{I}_i - \kappa_i(OD). \end{aligned}$$

The interaction term measures how the loss from shifting both reference points differs from the sum of the losses induced by shifting each separately. The combined incentive shift is smaller than the sum of the separate shifts when reference points overlap or message burden outweighs their complementarity. $\square$

Proposition A6. Dynamic effects depend on the persistence of salience and reference points. Suppose the salience, entitlement, and plan-reference effects evolve after a message according to:

$$s_{it}(k) = \delta_s^k s_i(t), \quad e_t(k) = e_0 + \delta_e^k [e(t) - e_0], \quad p_t(k) = p_0 + \delta_p^k [p(t) - p_0], \quad (\text{A.16})$$

where k is time since the message and $0 < \delta_s, \delta_e, \delta_p \leq 1$. Holding implementation effects and message burden fixed, the incentive shift is weakly decreasing in time since the message.

Proof. At time k , the behavioral shift is

$$\Gamma_i(t, k) = s_{it}(k) + \omega_i a(t) - \kappa_i(t) + \lambda_i L_i(e_t(k), p_t(k)).$$

For decay parameters below one, salience and the message-induced reference-point increments decline with k ; a parameter equal to one implies persistence of that component. Since $L_i(e, p)$ is weakly increasing in both arguments, the reference-dependent component cannot rise as the reference points return toward their baseline levels. Holding the remaining terms fixed, the incentive shift is therefore largest when the message is received. This result concerns the incentive to act at a given time; cumulative completion gaps need not decline because vaccinations already completed remain recorded.

A response concentrated near the suggested vaccination date requires an additional timing channel. For example, the plan reference point may become strongest around that date, rather than decay from the moment the message arrives. Such concentration would be consistent with a plan-based response, although timing alone cannot distinguish it from salience or implementation effects. $\square$

A.4 Link to the empirical design

Let Y_i denote second-dose completion. We relate the treatment comparisons to the estimating equation

$$Y_i = \alpha + \beta_P P_i + \beta_O O_i + \beta_D D_i + \beta_{OD} OD_i + X_i' \gamma + \varepsilon_i, \quad (\text{A.17})$$

where the omitted category is the pure control group and X_i denotes pre-treatment covariates. In this specification, β_P captures the effect of the implemented mental health message relative to no message. Comparing each active treatment with this placebo yields:

$$\tau_O = \beta_O - \beta_P, \quad \tau_D = \beta_D - \beta_P, \quad \tau_{OD} = \beta_{OD} - \beta_P. \quad (\text{A.18})$$

Under equal salience and the treatment mapping, τ_O captures the completion response to the entitlement shift; τ_D captures the joint response to the plan reference and implementation effects; and τ_{OD} captures their combination net of message burden. These interpretations depend on the maintained assumptions. The small, statistically insignificant placebo estimate indicates no detectable effect of the mental health message, but does not establish equal salience across arms or rule out a reminder effect from HPV-specific content.

The equality $\tau_O = \tau_D$ tests whether the implemented ownership and planning messages have the same average effect on completion. The model imposes neither equality nor a ranking. The comparison does not separately identify the contribution of each friction, since the messages may differ in how strongly they activate their intended channels or draw attention to vaccination.

The combined treatment allows us to test whether effects on completion relative to placebo are additive:

$$\tau_{OD} = \tau_O + \tau_D. \tag{A.19}$$

This equality is not implied by additive reference points and zero message-burden costs. Under equal salience, these conditions imply $\Delta_i^{OD} = \Delta_i^O + \Delta_i^D$, an equality of individual incentive shifts. Because completion follows a threshold rule, either message alone may induce the same parent to act, or both may be needed to induce a parent who responds to neither alone. The distribution of these responses determines whether the combined completion effect is below, equal to, or above the sum of the separate effects. Departures from additivity therefore do not by themselves identify substitution or complementarity between reference points. Comparisons with the single-message arms also vary the number of contacts; the two combined arms hold content and contact frequency constant while varying reminder timing.

The framework identifies the channels that each message may activate and the assumptions needed to interpret the treatment comparisons. Their relative effectiveness remains an empirical question.

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Appendix Tables

Table A-1: Variable Definitions

Component	Variable or construct	Definition and coding	Source or timing
<i>Panel A. Outcome and measurement window</i>			
Outcome	vaccinated	Indicator equal to one if administrative records show that the girl completed the HPV second dose during the follow-up window, and zero otherwise.	Administrative vaccination records
Outcome date	vaccination_date	Date of observed HPV second-dose completion among girls who completed the schedule; missing for non-completers.	Administrative vaccination records
Measurement window	win- Follow-up window	Completion is measured from April 25, 2022, through July 30, 2022. This is the window used for the final outcome and Kaplan-Meier curves.	Post-randomization
Campaign window	SMS campaign	The first SMS round was delivered on May 4, 2022, and the last SMS round was delivered on June 11, 2022.	Implementation records
<i>Panel B. Treatment assignment</i>			
Treatment arm	treat	Randomized arm indicator: 1 pure control; 2 placebo control; 3 ownership reminder; 4 planning prompt; 5 planning prompt plus ownership, 24h reminder; 6 planning prompt plus ownership, 2h reminder.	Random assignment
Pure control	pure_control	Indicator for the no-message control group.	Random assignment
Placebo control	placebo_control	Indicator for receiving an SMS from the Health Secretariat unrelated to HPV vaccination.	Random assignment
Ownership reminder	vaccine_reserv_only	Indicator for receiving SMS language stating that an HPV vaccine was reserved for the daughter.	Random assignment
Planning prompt	soft_default_only	Indicator for receiving SMS language suggesting a specific day and time for completing the HPV vaccination schedule.	Random assignment
Combined treatment, 24h	sft_dft_vaccine_reserv1	Indicator for receiving planning-prompt language plus an ownership reminder sent 24 hours before the suggested vaccination time.	Random assignment
Combined treatment, 2h	sft_dft_vaccine_reserv2	Indicator for receiving planning-prompt language plus an ownership reminder sent 2 hours before the suggested vaccination time.	Random assignment
<i>Panel C. Randomization strata</i>			
Strata	strata	Numeric fixed-effect identifier formed by baseline location crossed with the age-group indicator used in the randomization.	Pre-treatment administrative data
Location stratum	strata_location	Baseline location category used in the randomization strata.	Pre-treatment administrative data
Bogota indicator	bogota	Derived indicator equal to one if strata_location is Bogota D.C., and zero otherwise.	Constructed from strata
Age stratum	age	Indicator equal to one for girls ages 9–10 at baseline, and zero otherwise.	Pre-treatment administrative data
<i>Panel D. Baseline covariates</i>			
Age	age_girl	Girl's age in years at baseline.	Pre-treatment administrative data
Health insurer	sanitas, salud_total, famisanar, compensar, capital_salud, other_eps	Mutually exclusive indicators for the girl's health insurer; other_eps collects remaining insurers.	Pre-treatment administrative data
Health regime	regime_contri, regime_subsi, uninsured, another_regime	Indicators for contributory scheme, subsidized scheme, uninsured status, and other health-regime category.	Pre-treatment administrative data
Ethnicity	ethnicity	Indicator equal to one if the administrative records identify the girl as belonging to an ethnic group.	Pre-treatment administrative data
Displacement status	displaced	Indicator equal to one if the administrative records identify the girl as displaced by the armed conflict.	Pre-treatment administrative data
Nationality	colombian	Indicator equal to one if the girl's recorded nationality is Colombian.	Pre-treatment administrative data

Notes: This table defines the variables used in the econometric analysis. The sample includes 5,907 randomized parent records, each linked to one eligible girl; 819 girls completed the HPV second dose during the measurement window. The pure-control completion rate over this window is 8.6 percent. Treatment indicators identify mutually exclusive randomized assignments. Baseline covariates and strata are measured before treatment assignment.

Table A-2: Descriptive Statistics and Covariate Balance: Placebo-Control Benchmark

Variable	Descriptive statistics			Standardized differences relative to placebo control				
	Mean	SD	Placebo-control mean	Pure control	Ownership	Planning prompt	Planning+Own. 24h	Planning+Own. 2h
Girl's age (years)	11.252	2.013	11.278	-0.020	-0.017	-0.030	-0.001	-0.007
Age 9–10 years	0.461	0.498	0.460	0.002	0.002	0.001	0.003	0.001
Inside Bogota	0.628	0.483	0.627	0.002	0.001	0.001	0.001	0.003
EPS Sanitas	0.147	0.354	0.131	0.038	0.042	0.061	0.064	0.076
EPS Salud Total	0.101	0.301	0.105	-0.041	-0.016	-0.020	0.010	-0.003
EPS Famisanar	0.204	0.403	0.202	0.035	0.031	-0.021	0.003	-0.022
EPS Compensar	0.184	0.387	0.183	-0.008	0.032	0.005	-0.029	0.014
EPS Capital Salud	0.096	0.295	0.101	-0.017	-0.059	0.006	0.004	-0.020
Other EPS	0.268	0.443	0.279	-0.016	-0.040	-0.023	-0.038	-0.036
Contributory scheme	0.813	0.390	0.801	0.068	0.035	0.024	0.033	0.028
Subsidized scheme	0.123	0.328	0.131	-0.059	-0.049	-0.006	-0.015	-0.018
Uninsured	0.013	0.113	0.012	0.000	0.026	0.026	-0.009	0.000
Other health regime	0.051	0.220	0.056	-0.032	-0.004	-0.046	-0.032	-0.022
Belongs to an ethnic group	0.005	0.071	0.005	-0.051	0.014	0.026	-0.032	0.026
Displaced by armed conflict	0.012	0.110	0.010	0.019	0.046	-0.000	-0.021	0.069
Colombian nationality	0.963	0.189	0.959	0.049	-0.011	0.021	0.037	0.010
Observations	5907		985	985	983	986	984	984

Notes: This table reports descriptive statistics and covariate balance for the final analysis sample. The first two columns report the full-sample mean and standard deviation. The third column reports the mean for the placebo-control group. The remaining columns report signed standardized differences between each listed arm and the placebo-control group, computed as the difference in means divided by the square root of the average of the two group-specific variances. Values close to zero indicate stronger balance. The covariates are measured before treatment assignment and come from administrative records. The pure control group received no message; the placebo-control group received an SMS unrelated to HPV vaccination content; ownership refers to language indicating that an HPV vaccine was reserved for the daughter; and planning prompt refers to language suggesting a specific day and time for completing the vaccination schedule.

Table A-3: Alternative Benchmarks for Main ITT Effects

	(1) Pure-control benchmark	(2) Placebo-control benchmark	(3) Pooled-control benchmark
Placebo control	0.0143 (0.0130)	—	—
Ownership reminder	0.0458*** (0.0139)	0.0315** (0.0143)	0.0386*** (0.0125)
Planning prompt	0.0867*** (0.0147)	0.0724*** (0.0150)	0.0795*** (0.0133)
Planning prompt + ownership, 24h	0.0794*** (0.0146)	0.0652*** (0.0149)	0.0723*** (0.0133)
Planning prompt + ownership, 2h	0.0910*** (0.0148)	0.0768*** (0.0152)	0.0839*** (0.0135)
Benchmark mean	0.0863	0.0995	0.0929
Benchmark observations	985	985	1,970
Regression observations	5907	5907	5907
Strata fixed effects	Yes	Yes	Yes
Pre-treatment covariates	Yes	Yes	Yes
P-value: active arms equal	0.015	0.015	0.015

Notes: The dependent variable is an indicator equal to one if the girl completed the HPV second dose during the study period, measured in administrative vaccination records. Coefficients and standard errors are reported in the original 0–1 scale of the dependent variable. Column 1 estimates effects relative to the pure control group and includes the placebo-control arm as a separate non-omitted treatment indicator. Column 2 estimates effects relative to the placebo control group and includes the pure control group as a separate non-omitted category; the placebo row is therefore not applicable in this column. Column 3 pools the pure and placebo controls as the omitted benchmark; the placebo-control row is therefore part of the benchmark. All specifications are linear probability models with randomization-strata fixed effects and the same pre-treatment administrative covariates used in the covariate-adjusted specification of Table 3: EPS indicators, health-regime indicators, ethnicity, displacement status, Colombian nationality, and girl’s age. The equality-test p-value tests equality of the four active treatment arms: ownership reminder, planning prompt, planning prompt plus ownership at 24 hours, and planning prompt plus ownership at 2 hours. Robust standard errors are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A-4: Full Multiple-Hypothesis Testing Q-Values

Hypothesis	Benchmark or contrast	Estimate	Robust SE	Robust p	BH q	BKY q
<i>Panel A. Main ITT vs pure control ($m = 5$)</i>						
Placebo control	Pure control	0.0143	(0.0130)	0.274	0.274	0.058
Ownership reminder	Pure control	0.0458	(0.0139)	0.001	0.001	≤ 0.001
Planning prompt	Pure control	0.0867	(0.0147)	< 0.001	≤ 0.001	≤ 0.001
Planning prompt + ownership, 24h	Pure control	0.0794	(0.0146)	< 0.001	≤ 0.001	≤ 0.001
Planning prompt + ownership, 2h	Pure control	0.0910	(0.0148)	< 0.001	≤ 0.001	≤ 0.001
<i>Panel B. Active arms vs placebo control ($m = 4$)</i>						
Ownership reminder	Placebo control	0.0315	(0.0143)	0.028	0.028	0.007
Planning prompt	Placebo control	0.0724	(0.0150)	< 0.001	≤ 0.001	≤ 0.001
Planning prompt + ownership, 24h	Placebo control	0.0652	(0.0149)	< 0.001	≤ 0.001	≤ 0.001
Planning prompt + ownership, 2h	Placebo control	0.0768	(0.0152)	< 0.001	≤ 0.001	≤ 0.001
<i>Panel C. Active arms vs pooled controls ($m = 4$)</i>						
Ownership reminder	Pure + placebo controls	0.0386	(0.0125)	0.002	0.002	≤ 0.001
Planning prompt	Pure + placebo controls	0.0795	(0.0133)	< 0.001	≤ 0.001	≤ 0.001
Planning prompt + ownership, 24h	Pure + placebo controls	0.0723	(0.0133)	< 0.001	≤ 0.001	≤ 0.001
Planning prompt + ownership, 2h	Pure + placebo controls	0.0839	(0.0135)	< 0.001	≤ 0.001	≤ 0.001
<i>Panel D. Mechanism contrasts ($m = 6$)</i>						
Any message	Pure control	0.0757	(0.0106)	< 0.001	≤ 0.001	≤ 0.001
Ownership cue	Pure control	0.0458	(0.0139)	0.001	0.002	0.001
Planning prompt	Pure control	0.0867	(0.0147)	< 0.001	≤ 0.001	≤ 0.001
Ownership cue x planning prompt	Pure control	-0.0530	(0.0215)	0.014	0.017	0.008
2h vs 24h timing	24h combined arm	0.0116	(0.0165)	0.484	0.484	0.088
Ownership cue - planning prompt	Internal contrast	-0.0409	(0.0158)	0.010	0.015	0.007

Notes: The dependent variable is an indicator equal to one if the girl completed the HPV second dose during the study period, measured in administrative vaccination records. Estimates come from covariate-adjusted linear probability models with randomization-strata fixed effects, Eicker-Huber-White robust standard errors, and the same pre-treatment covariates used in Table 3. Panels A–C report treatment-arm contrasts under the benchmark definitions used in Tables 3 and A-3. Panel D reports the mechanism and component-model hypotheses from Table 4; the ownership-planning row reports the linear contrast between the ownership and planning-prompt coefficients. BH q -values control the false discovery rate within each panel using the procedure of Benjamini and Hochberg (1995). BKY q -values use the two-stage sharpened adjustment of Benjamini et al. (2006), following Anderson (2008), with each panel defining a family of hypotheses. Coefficients and standard errors are reported in the original 0–1 scale of the dependent variable.

Table A-5: Generic Machine Learning: Classification Analysis

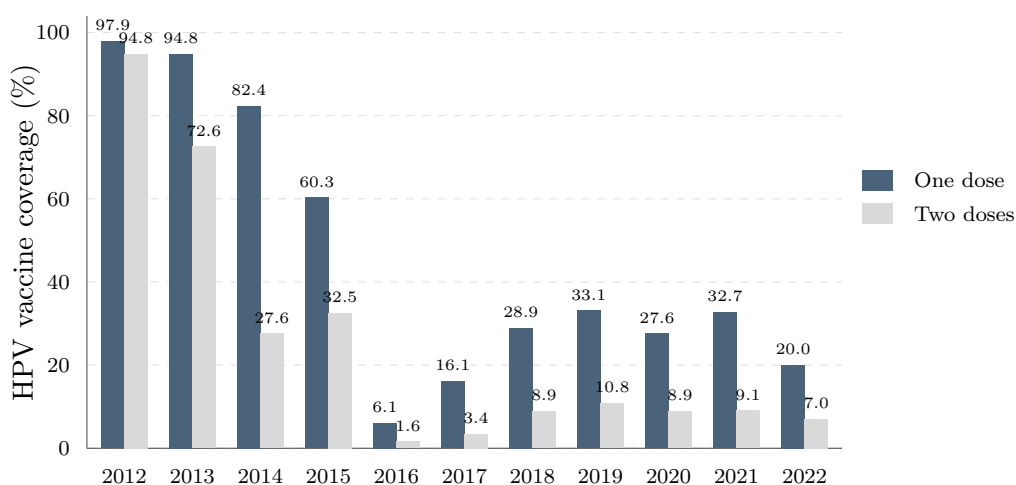
Characteristic	G1: lowest predicted gain	G5: highest predicted gain	Difference	90% CI	<i>p</i> -value
EPS Sanitas	8.47	28.79	17.73	[13.90, 22.12]	< 0.001
EPS Salud Total	15.15	1.17	-14.76	[-18.02, -11.70]	< 0.001
EPS Famisanar	20.44	17.63	-3.36	[-7.74, 1.47]	0.185
EPS Compensar	14.59	21.22	6.08	[2.60, 10.75]	0.004
EPS Capital Salud	4.12	11.62	7.24	[4.04, 10.29]	< 0.001
Contributory regime	84.59	79.39	-4.33	[-8.46, 0.10]	0.080
Uninsured	2.67	0.20	-2.37	[-3.85, -0.93]	0.001
Subsidized regime	6.10	14.44	8.48	[4.96, 11.99]	< 0.001
Ethnic minority	1.84	0.00	-1.84	[-3.05, -0.65]	0.003
Displaced	0.85	1.42	0.47	[-0.71, 1.78]	0.460
Colombian national	94.13	99.30	5.15	[2.81, 7.35]	< 0.001
Girl's age	13.92	9.55	-4.42	[-4.58, -4.26]	< 0.001
Age 9-10	0.52	95.37	94.46	[92.73, 96.28]	< 0.001
Inside Bogota	6.04	99.80	92.77	[90.59, 95.01]	< 0.001
Subsidized or uninsured	9.89	15.00	5.92	[2.04, 9.41]	0.004

Notes: The table reports classification analysis (CLAN) following Chernozhukov et al. (2025). G1 and G5 are the quintiles with the lowest and highest predicted treatment gains, respectively. The outcome is completion of the second HPV vaccine dose. The analysis compares assignment to any of the four active messages with the pure-control arm and excludes the placebo. For each of 100 sample splits, one half of the observations is used to predict treatment gains from pre-treatment characteristics and the other to estimate the target parameters. Estimates and confidence limits are aggregated across splits using medians. Binary characteristics are expressed as percentages, and differences as percentage points; age is measured in years. The 90% confidence interval and *p*-value refer to the difference between G5 and G1. Because each statistic is aggregated separately, the reported difference need not equal the difference between the displayed group means.

Appendix Figures

Figure A-1 documents the national trajectory of HPV vaccination coverage following the introduction of the vaccine in Colombia. The PAI series shows a sharp decline in both one-dose and two-dose coverage after the initial years of the program and persistently low coverage through 2022.

Figure A-1: HPV Vaccination Rates in Colombia Since the Introduction of the Vaccine in 2012



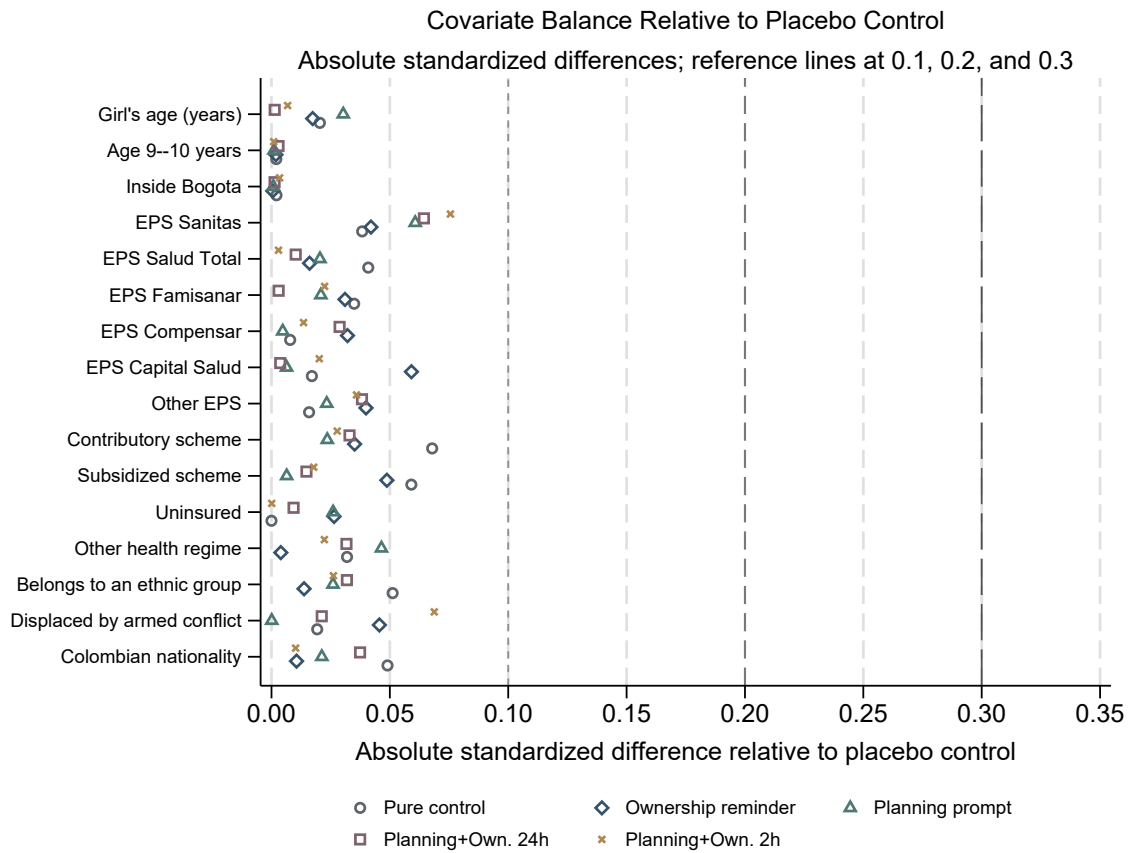
Notes: The bars report annual national HPV vaccination coverage for one and two doses. Source: Authors' elaboration based on data from the Information System of the Expanded Immunization Program (PAI) of the Ministry of Health and Social Protection of Colombia.

Figure A-2: SMS Content by Treatment Arm

Experimental arm	Message content
Placebo control	Hello Fransheska. Take care of your mental health. Exercise, meditate, eat well and get adequate sleep. Secretary of Health.
Ownership reminder	Hello Lucila. There is an HPV vaccine reserved for your daughter. Secretary of Health.
Planning prompt	Hello Fransheska. You have an appointment on May 21 at 10 a.m. to vaccinate your daughter against HPV. Secretary of Health.
Planning prompt + ownership reminder, 24h	Message 1 (62 hours prior to the appointment): Hello Maria. You have an appointment on May 21 at 10 a.m. to vaccinate your daughter against HPV. Secretary of Health. Message 2 (24 hours prior to the appointment): Hello Maria. Remember that there is an HPV vaccine reserved for your daughter. Secretary of Health.
Planning prompt + ownership reminder, 2h	Message 1 (62 hours prior to the appointment): Hello Raquel. You have an appointment on May 21 at 10 a.m. to vaccinate your daughter against HPV. Secretary of Health. Message 2 (2 hours prior to the appointment): Hello Raquel. Remember that there is an HPV vaccine reserved for your daughter. Secretary of Health.

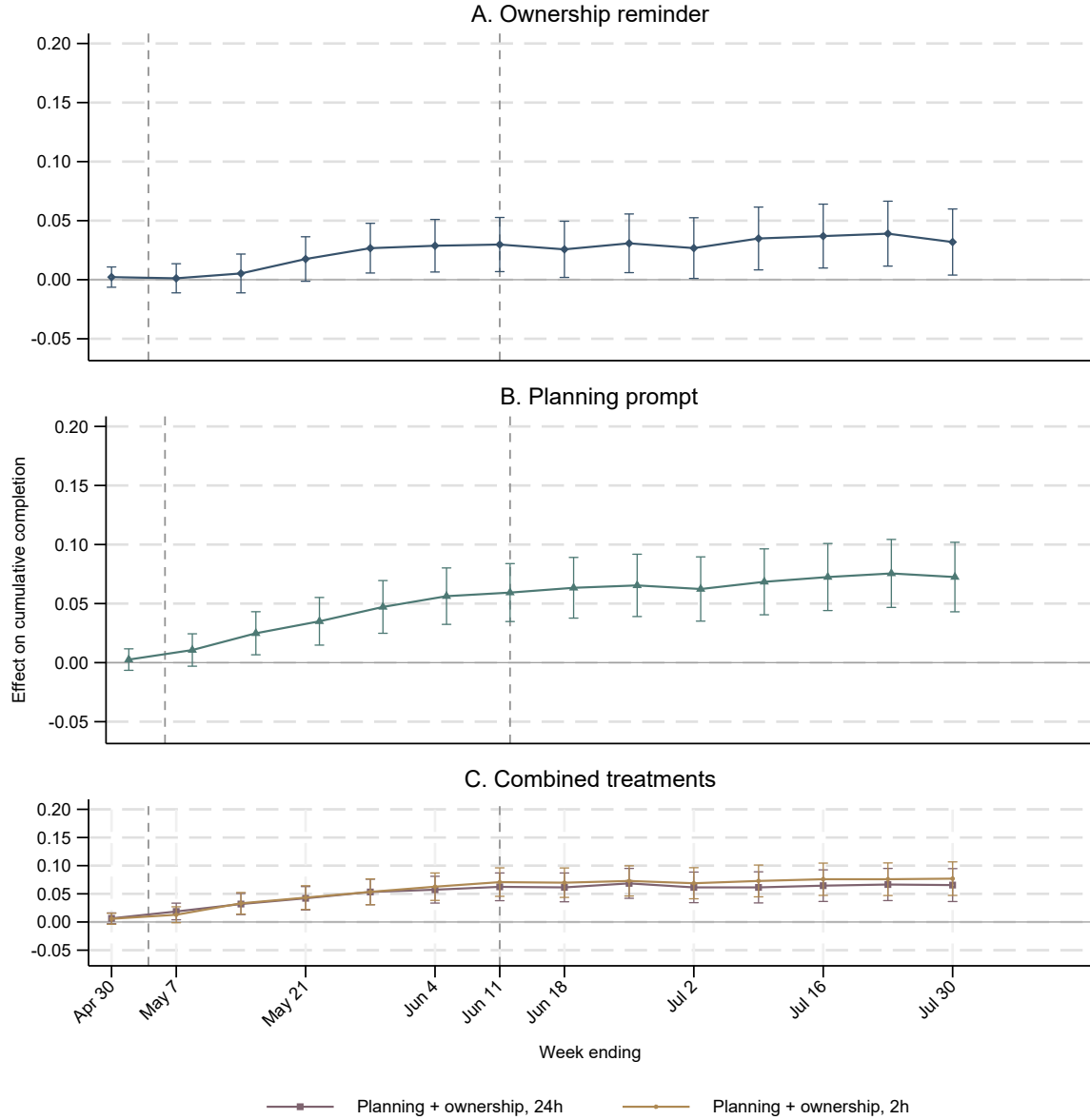
Notes: The figure presents the message content for each treatment arm. The displayed names illustrate personalization: each message addressed the parent by first name. All messages identified the Health Secretariat as the sender. The placebo message provided mental health advice without HPV-vaccination content; the pure control group received no SMS. Although planning prompts used appointment language, the day and time were suggestions for vaccination. No individual appointment was scheduled or vaccination slot reserved.

Figure A-3: Covariate Balance Plot Relative to Placebo Control



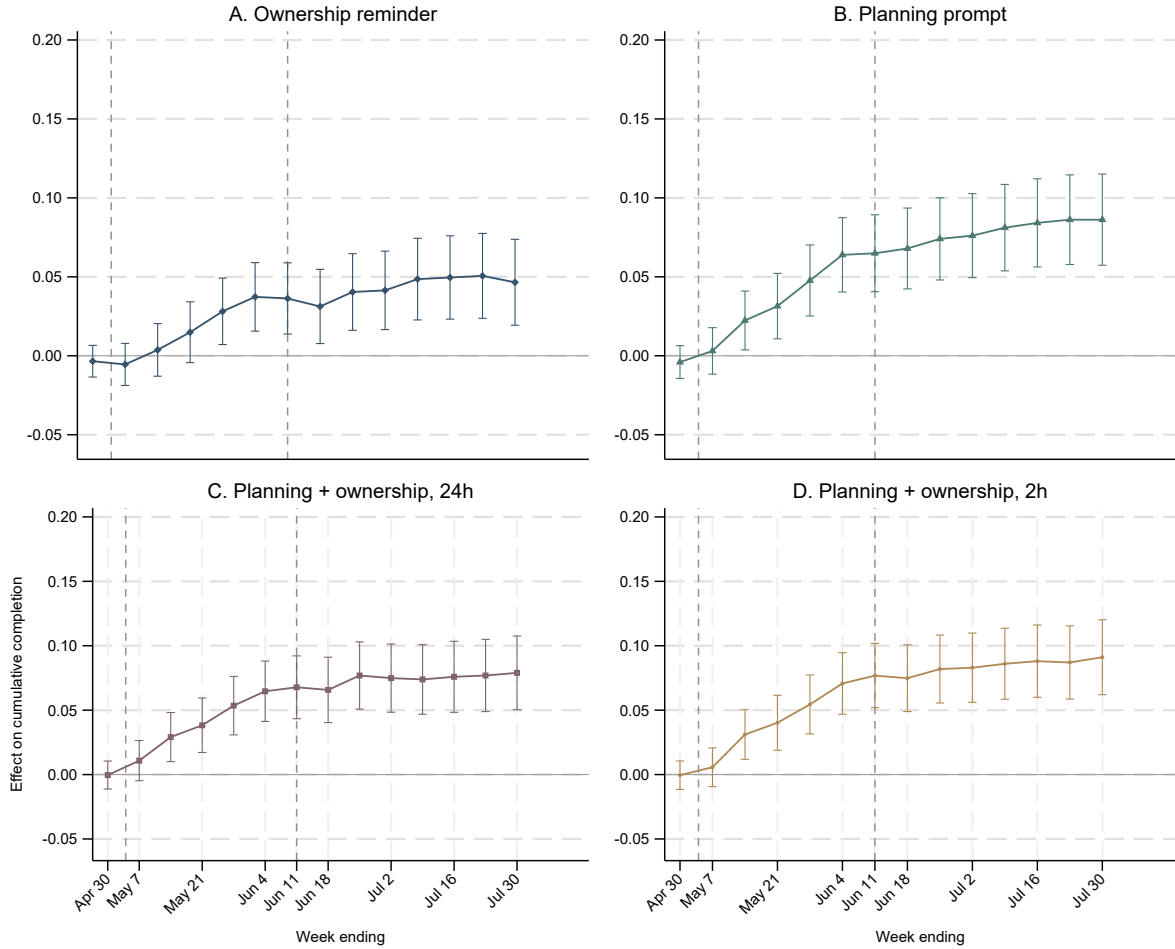
Notes: The figure reports absolute standardized differences in baseline covariates between each non-placebo-control arm and the placebo control group. Standardized differences are computed as the difference in group means divided by the square root of the average of the two group-specific variances. Vertical reference lines mark conventional thresholds of 0.1, 0.2, and 0.3 in absolute standardized-difference units. Values closer to zero indicate stronger covariate balance. Covariates are measured before treatment assignment and come from administrative records.

Figure A-4: Dynamic Treatment Effects Relative to Placebo Control



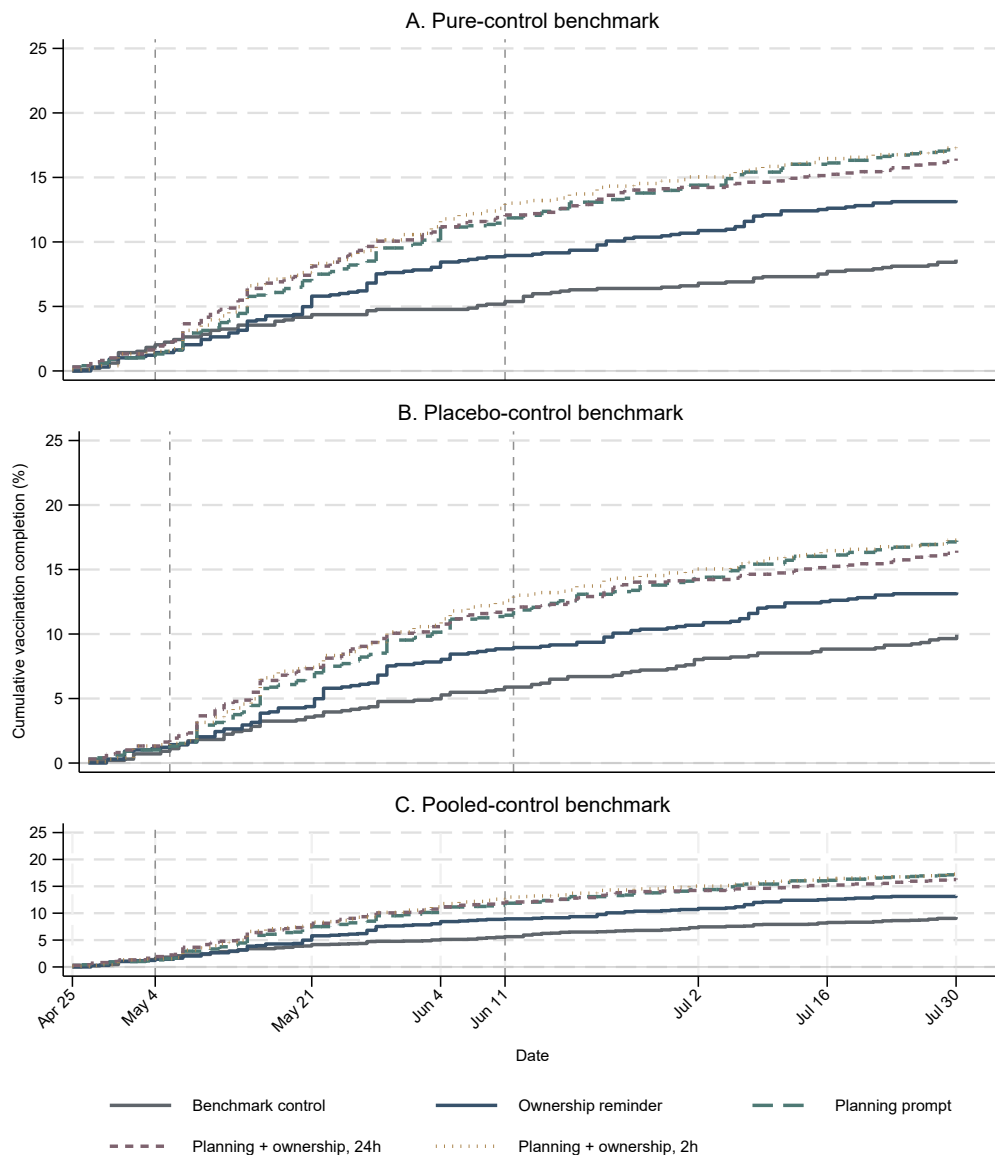
Notes: The figure reports weekly treatment effects on cumulative HPV second-dose completion relative to the placebo-control group. Panel A reports the ownership reminder arm; Panel B reports the planning-prompt arm; Panel C reports the two combined planning-prompt plus ownership-reminder arms. Outcomes are cumulative indicators equal to one if the girl had completed the second dose by the end of each calendar week. Estimates come from linear probability models in the stacked girl-week panel and include week fixed effects, randomization-strata fixed effects, and the same baseline covariates used in the main ITT specification. Vertical dashed lines mark the first SMS delivery on May 4, 2022, and the last SMS delivery on June 11, 2022. Error bars are 95 percent confidence intervals based on standard errors clustered at the girl level.

Figure A-5: Arm-by-Arm Dynamic Treatment Effects



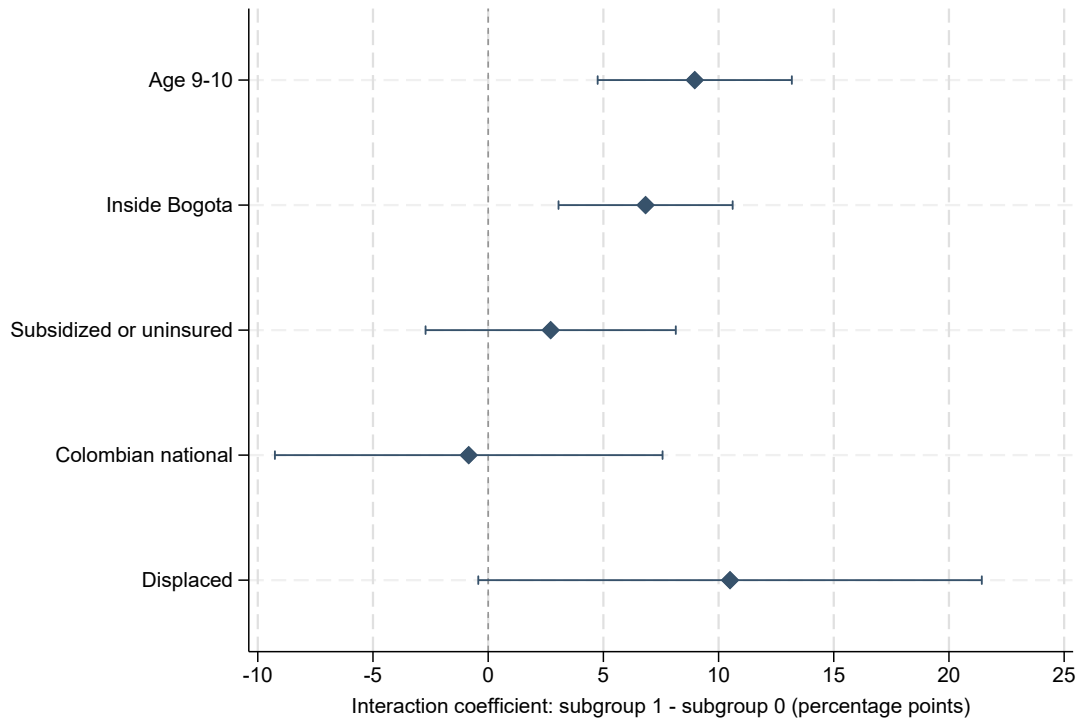
Notes: Each panel reports weekly treatment effects on cumulative HPV second-dose completion relative to the pure control group for one active treatment arm. Outcomes are cumulative indicators equal to one if the girl had completed the second dose by the end of each calendar week. Estimates come from linear probability models in the stacked girl-week panel and include week fixed effects, randomization-strata fixed effects, and the same baseline covariates used in the main ITT specification. Vertical dashed lines mark the first SMS delivery on May 4, 2022, and the last SMS delivery on June 11, 2022. Error bars are 95 percent confidence intervals based on standard errors clustered at the girl level.

Figure A-6: Kaplan-Meier Completion Curves by Alternative Control Benchmark



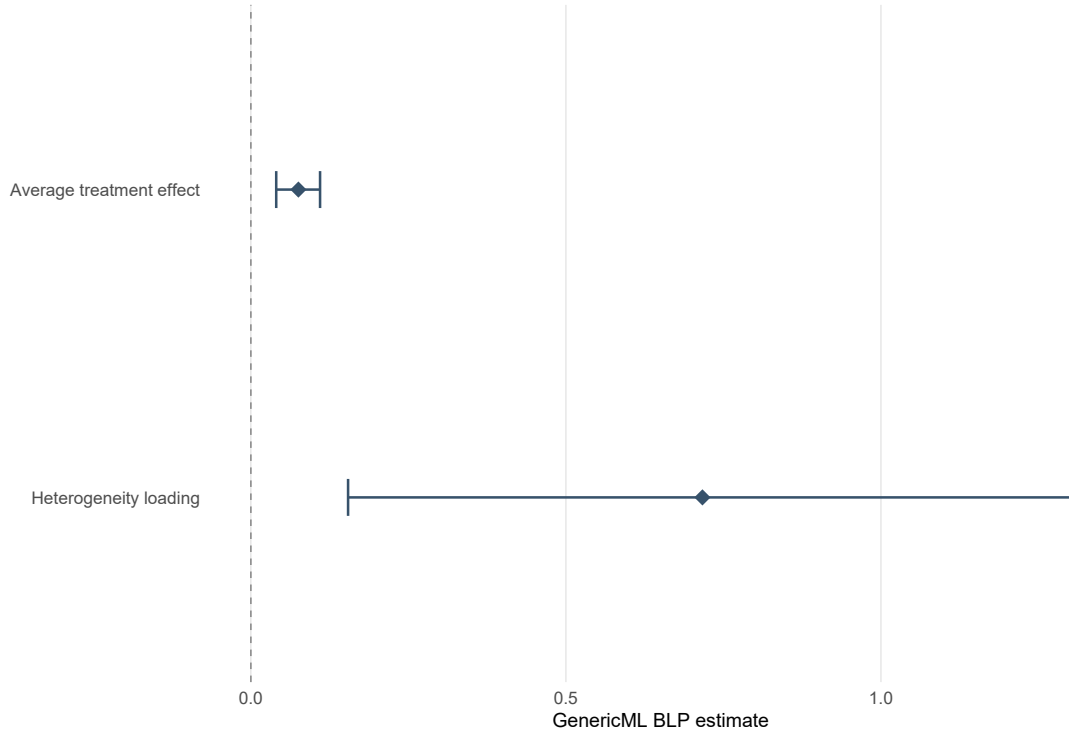
Notes: Each panel plots cumulative HPV second-dose completion during the administrative follow-up window for one control benchmark and the four active treatment arms. Panel A uses the pure control group as the benchmark; Panel B uses the placebo-control group; Panel C pools the pure and placebo control groups. The time axis begins on April 25, 2022, the first observed vaccination date in the follow-up data, and ends on July 30, 2022. Vertical dashed lines mark the first SMS delivery on May 4, 2022, and the last SMS delivery on June 11, 2022. Because there is only administrative censoring at the end of follow-up, the plotted curves are equivalent to cumulative completion rates by date.

Figure A-7: Heterogeneity Coefficient Plot



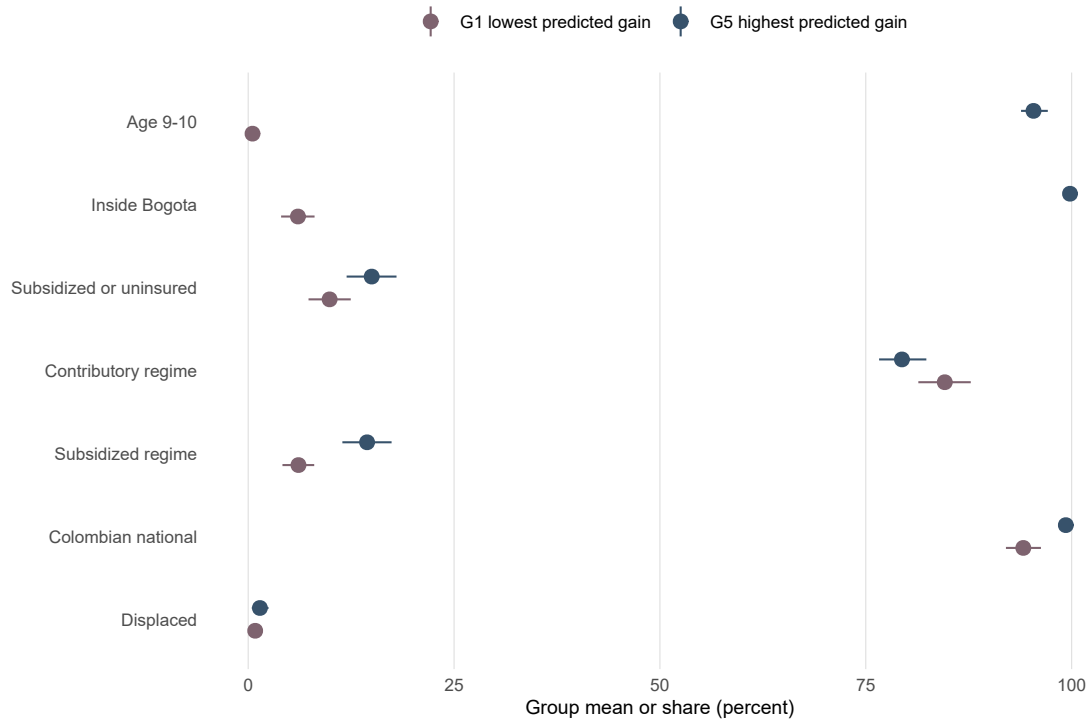
Notes: Each point is the interaction coefficient between the indicator for receiving any of the four active messages and the pre-specified subgroup indicator shown on the vertical axis. The estimation sample excludes the placebo-control arm and compares the pure control group with the four active treatment arms. Coefficients are reported in percentage points. All specifications are linear probability models with randomization-strata fixed effects and the same pre-treatment administrative covariates used in Table 3. Horizontal bars report 95 percent confidence intervals based on Eicker-Huber-White robust standard errors. The corresponding arm-specific interaction estimates are reported in Table 6.

Figure A-8: Generic Machine Learning: Best Linear Predictor



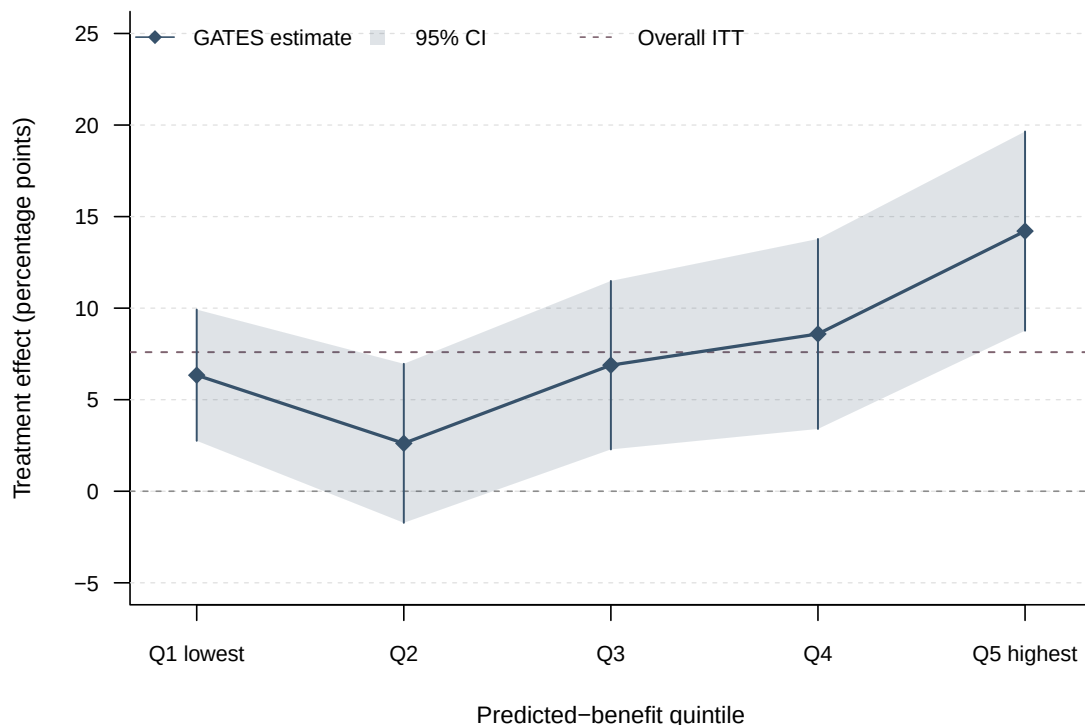
Notes: The figure reports the best linear predictor (BLP) of treatment effects using the framework of Chernozhukov et al. (2025). The outcome is completion of the second HPV vaccine dose. The analysis compares assignment to any of the four active messages with the pure-control arm and excludes the placebo. The coefficient β_1 measures the average treatment effect on the 0–1 completion scale; β_2 measures whether the predicted-gain score captures treatment-effect heterogeneity. Testing $\beta_2 = 0$ assesses the predictive content of that score. For each of 100 sample splits, one half of the observations is used to predict treatment gains from pre-treatment characteristics and the other to estimate the target parameters. Estimates and confidence limits are aggregated across splits using medians. Horizontal bars show 90% confidence intervals.

Figure A-9: Generic Machine Learning: Classification Analysis



Notes: The figure reports classification analysis (CLAN) following Chernozhukov et al. (2025). It compares selected baseline characteristics in the quintiles with the lowest (G1) and highest (G5) predicted treatment gains. The outcome is completion of the second HPV vaccine dose. The analysis compares assignment to any of the four active messages with the pure-control arm and excludes the placebo. For each of 100 sample splits, one half of the observations is used to predict treatment gains from pre-treatment characteristics and the other to estimate the target parameters. Estimates and confidence limits are aggregated across splits using medians. Points show group shares in percent, and horizontal bars show 90% confidence intervals. Table A-5 reports all characteristics and tests of the differences between G5 and G1.

Figure A-10: Group Average Treatment Effects Using a Cross-Fitted Regression-Tree Score



Notes: The figure reports treatment effects by quintile of predicted gains from regression-tree outcome models. The outcome is completion of the second HPV vaccine dose. The analysis compares assignment to any of the four active messages with the pure-control arm and excludes the placebo. Predictions use five-fold cross-fitting: separate outcome models for treated and control observations are estimated on four folds using pre-treatment covariates and randomization-strata indicators, then applied to the remaining fold. Each parent's predicted gain is the difference between these predictions. Quintiles rank these gains from lowest to highest. Group effects are estimated jointly in a linear probability model with treatment-by-quintile interactions, quintile fixed effects, randomization-strata fixed effects, and pre-treatment covariates. Effects are expressed in percentage points. The shaded region shows 95% confidence intervals based on Eicker–Huber–White robust standard errors, and the dashed line shows the overall covariate-adjusted intention-to-treat effect. This exercise assesses sensitivity to the construction of the predicted-gain score relative to Figure 8. The joint test of equal effects across quintiles has $p = 0.024$; the linear trend test has $p = 0.004$.

B Pre-Analysis Plan

The experiment was registered in the AEA RCT Registry under ID AEARCTR-0009705.

The complete pre-analysis plan is reproduced below.⁷

⁷The document reproduced in this appendix is the original version available through the AEA RCT Registry at <https://www.socialscienceregistry.org/trials/9705>. Its original terminology, including references to “soft defaults” and “default options,” is retained verbatim. The manuscript refers to the implemented intervention as a planning prompt.

Applying Behavioral Insights for Encouraging Parents to Vaccinate their Daughters against HPV in Colombia

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July 8, 2022

Pre-Analysis Plan

Abstract

We conducted a text SMS campaign leveraging the lessons from behavioral sciences to increase vaccine take-up against the Human Papillomavirus (HPV) in Colombia. In particular, these messages integrate behavioral insights in dimensions related to altruism, warm-glow giving, default options, reminders, and beliefs.

1 Introduction

In 2020 approximately 342,000 women died from cervical cancer (CC), and around 90 percent of the deaths occurred in low- and middle-income countries. (Sung et al., 2021). The main cause of cervical cancer is the Human Papillomavirus (HPV), preventable by a cost-effective solution such as vaccination. However, in Latin America, a significant reduction in HPV vaccination coverage has occurred in the years following its inclusion in the vaccination plans (Nogueira-Rodrigues, 2019). Consequently, there is a serious public health problem in the region. Since many women are still unimmunized and the long-term consequences are devastating. Hence, the interest of governments in promoting effective HPV vaccination

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campaigns.

For this project, we conducted large-scale experiments based on behavioral sciences to increase the uptake of the HPV vaccine in Colombia. Specifically, we implemented a behavioral-based short messaging service (SMS) campaign targeting parents in Colombia. Text messages include behavioral lessons such as altruism, warm-glow giving, default options, reminders, and beliefs. These interventions were implemented in partnership with the American Cancer Society, the Behavioral Government Lab (Universidad del Rosario), the Inter-American Development Bank, the Health Secretariat (HS) of the City of Bogotá, and the Liga Colombiana contra el Cáncer.

This document describes the pre-analysis plan to assess the impact of the SMS campaign. Since this plan was written before final data were requested and analyzed (August 2022), it provides an essential reference to evaluate the performance of these interventions. The plan is outlined as follows: Section 2 reviews the background of the study; Section 3 explains the setting of the experiment; Section 4 defines the interventions; Section 5 describes the sample and the data; section 7 summarizes the study hypotheses; Section 6 explains the power calculations; Section 8 describes the research design, and Section 9 the estimation strategy. The Appendix offers details about our research design.

2 Background

Colombia is a particular case regarding HPV vaccination, as according to Nogueira-Rodrigues (2019) in 2013, the vaccination coverage of first doses was 97.5%, the second-best rate worldwide after Australia. A significant part of its success is attributable to the campaign implemented in 2012 in schools across the country, where girls over nine years of age were vaccinated. Nevertheless, in 2014 an outbreak of unknown etiology occurred in the municipality of Carmen de Bolívar; around 500 girls who had been immunized against HPV presented headaches, fainting, and numbness of extremities. Some families in the municipality and

anti-vaccine movements claimed that the HPV vaccination was the cause of the outbreak. This case led to a huge controversy surrounding the vaccine and bad publicity in the media. So vaccination rates dropped precipitously, to the point that by 2016 coverage for first doses was 14% and 9% for second doses (Simas et al., 2019). However, the Colombian Ministry of Health and Social Protection, in conjunction with the National Institute of Health, conducted an epidemiological study in which they demonstrated that it was not possible to associate HPV vaccination with the events in Carmen de Bolívar (Martínez et al., 2015). Similarly, several international studies have confirmed the safety of the vaccine. In particular, Phillips et al. (2018) identified 109 studies demonstrating that all HPV vaccines have an acceptable safety profile.

Following the Carmen de Bolívar incident, much political instability was generated around the vaccine. Therefore, the Colombian state preferred to withdraw its support for HPV vaccination and adopt a more indifferent stance. The school campaign was interrupted, and the government decided to incorporate informed consent so that the parents would have the autonomy to decide whether to vaccinate their daughters. Provoking an additional barrier since other vaccines in the vaccination plan do not require informed consent.

Despite little government support, institutions such as the Liga Colombiana Contra el Cáncer and the American Cancer Society have made several efforts to improve HPV vaccination coverage in the country. In Arauca (a city in Colombia), for example, an educational campaign was developed targeting the different members of the HPV vaccination process. After the campaign, vaccination rates in Arauca went from 5% in 2017 to 41% in 2018 and 83 % in 2019 (Castro et al., 2020). So the Liga has made great progress. However, there is still great room for improvement in the rest of the country, especially in the teachings of behavioral sciences. Since its solutions, in many cases, are low cost and easy to implement.

3 Setting

Before designing any public policy, it is necessary to have a thorough understanding of the problem to be solved. In the case of low HPV vaccination rates, there is a vast literature on the reasons. One plausible explanation is the beliefs that people may form about the vaccine and HPV. Another possible cause is procrastination, with parents postponing HPV vaccination. We, therefore, developed a series of interventions that address these causes and take advantage of the altruistic behaviors of parents toward their daughters.

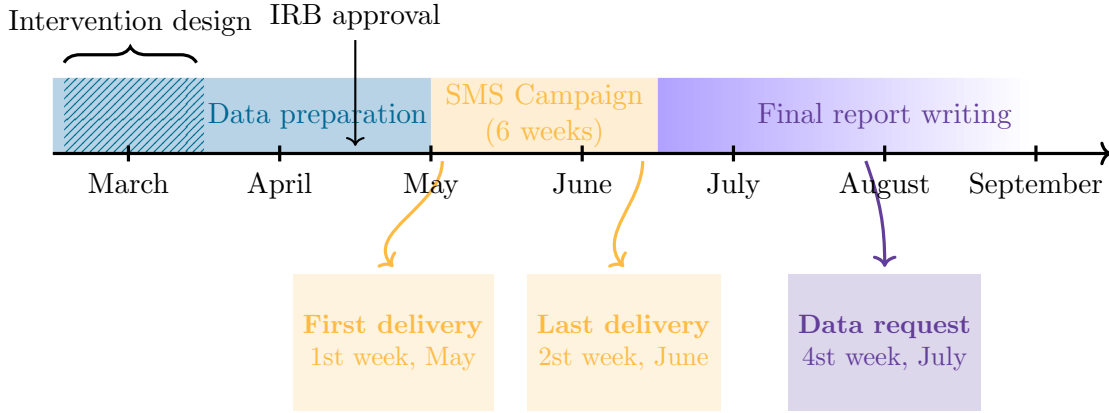
The implementation of the SMS campaign was possible due to the administrative data of HS. Colombia has an excellent immunization program (PAI) that covers the entire population, and it does not matter whether the person is insured in the health system. Regarding the information on the vaccines, this is uploaded to the application (PAIWEB) by the health providers. These reports will be crucial in evaluating the effectiveness of the interventions.

4 Interventions

The study included three types of experiments designed to improve the HPV vaccination rates in this setting. The first type of experiment focuses on altruism and its distinction with warm-glow giving. The second uses soft default options and some insights from Milkman et al. (2021). The third may aim to correct parents' beliefs about the HPV vaccine. Each experiment included two fixed components in its messages: the name of the person to whom the message was sent and the message's sender. We added the fixed components to make the message more personalized, as other settings have shown it to be effective. For the population of unvaccinated girls we implemented all three types of experiments.

In contrast, only the default options and milkman insights were applied to girls with incomplete HPV vaccination schedules. The reason for this was that there was not enough sample for girls with incomplete HPV vaccination schedules to conduct further experiments. The timeline

Figure 1: Experiment Timeline



of these experiments is presented in figure 1 and the interventions are described in detail below.

4.1 Experiment 1: Altruism and warm-glow

Experiment 1 exploits the altruism of fathers towards their daughters and their desire to protect them. Specifically, we present two versions: a soft and a strong version. In the soft version, the word “need” is used to show parents that their daughters need their help, which could be considered something usual because parents, in theory, are constantly helping their children. In addition, at the end of the message, it is emphasized that the parent will be protecting her daughter against cervical cancer. In the strong version, the imminent danger of cervical cancer is made salient by using the expression “Save your daughter,” At the end, the message emphasizes that the parent will be giving her all the protection.

On the other hand, we added two treatments of the economic theory of Warm-glow. Specifically, one exploits intrinsic Warm-glow and the other extrinsic Warm-glow. Intrinsic Warm-glow refers to the personal satisfaction of helping others. Extrinsic Warm-glow indicates that external rewards may be involved, such as recognition and prestige. The content of the text messages for this intervention is presented in the graph (2).

Figure 2: SMS Content for experiment 1

Altruism: a soft feeling of protecting	Hello Dayana. Your daughter needs you, vaccinate her against HPV and protect her from cervical cancer. Secretary of Health.
Altruism: a strong feeling of protecting	Hello Luciana. Save your daughter from cervical cancer. Vaccinate her against HPV and give her all the protection. Secretary of Health.
Warm-glow Intrinsic	Hello Aura. Vaccinate your daughter against HPV and be glad to protect her from cervical cancer. Secretary of Health.
Warm-glow Extrinsic	Hello Silvia. Vaccinate your daughter against HPV and join the list of responsible parents who protect their daughters against cancer. Secretary of Health.

4.2 Experiment 2: Beliefs

This experiment provided information to correct parental beliefs regarding HPV vaccination and the severity of HPV. One of the treatments includes a short 2-minute YouTube video designed by La Liga Colombiana contra el Cáncer that provides general information about HPV vaccination. The other two treatments address the ideal timing of HPV vaccination and the severity of HPV globally. Figure (3) presents the messages used in this intervention.

Figure 3: SMS Content for experiment 2

Beliefs in general	Hello Sofia. For more information on HPV vaccination, watch a 2-minute video: https://youtu.be/FZOIYXwwLk0 . Secretary of Health.
Beliefs about vaccination timing	Hello Danna. Did you know that the sooner you vaccinate your daughter against HPV the better? Don't miss out on the benefits of doing it early. Secretary of Health.
Beliefs about severity global	Hello Laura. Did you know that more than 324,000 women worldwide die every year due to HPV? Vaccinate your daughter against HPV. Secretary of Health.

4.3 Experiment 3: Decision aids

In this intervention, we implemented the soft default options and one of the insights from Milkman et al. (2021). For the soft default options, we suggested a time and day for parents to go and vaccinate their daughters. Then, following the methodology of Milkman et al. (2021), the message “an HPV vaccine reserved for your daughter” is used as a reminder of the previous message. Because, as the authors explain, the language makes parents feel that the vaccine belongs to their daughters, and therefore they do not want to miss “their” dose. We carried out two versions of reminders: one 24 hours before the appointment and the other 2 hours before the appointment. In Figure (4) we can see in detail the wording of the text messages based on these dimensions.

Figure 4: SMS Content for experiment 3

Milkman’s insight (1SMS)	Hello Valeria. There is an HPV vaccine reserved for your daughter. Secretary of Health.
Soft-default (1 SMS)	Hello Lucila. You have an appointment on June 21 at 10 a.m. to vaccinate your daughter against HPV. Secretary of Health.
Soft-default + Milkman’s insight (2 SMS option 1)	Message 1 (62 hours prior to the appointment): Hello Maria. You have an appointment on June 21 at 10 a.m. to vaccinate your daughter against HPV. Secretary of Health. Message 2 (24 hours prior to the appointment): Hello Maria. Remember that there is an HPV vaccine reserved for your daughter. Secretary of Health.
Soft-default + Milkman’s insight (2 SMS option 2)	Message 1 (62 hours prior to the appointment): Hello Mariana. You have an appointment on June 21 at 10 a.m. to vaccinate your daughter against HPV. Secretary of Health. Message 2 (2 hours prior to the appointment): Hello Mariana. Remember that there is an HPV vaccine reserved for your daughter. Secretary of Health.

5 Data

The Health Secretariat of Bogota provided the data for the experiments. One of the advantages of these data is that health providers upload information regarding vaccinations for all citizens. Therefore, we will be able to observe whether the girl was vaccinated or not. However, there are limited pre-treatment covariates. Among these covariates are the health care provider (EPS), if the person belongs to the contributory or subsidized regime, nationality, ethnicity, displacement by civil war, and daughter’s age.

Regarding the sample, the first dataset corresponds to parents with unvaccinated daughters against HPV between 9 and 17 years of age. The second dataset corresponds to girls who have only one dose of the vaccine (incomplete schedule). Specifically, part of the excluded sample from an allied research study, “Nudging parents to increase HPV vaccine demand in Bogota, Colombia,” was used. The reason for this data exclusion was that this information was required for the stratified randomization and the social norms experiment. However, in the experiments presented above, it is not necessary to have this information. Thus, we took advantage of these samples to conduct other interventions. Finally, the resulting sample for unvaccinated girls is 16,538 parents. At the same time, the sample for girls with incomplete schedules is 5,907 parents. Descriptive statistics for unvaccinated girls are presented in the table (1) and for girls with incomplete immunization schedules are presented in the table (2).

6 Power calculations

We estimated the minimum sample size for each experiment assuming an individual randomized design with an effect size of 4.25 percentage points, 90% power, and a Chi-Square test for difference of proportions at a 5% significance level. Because each experiment has up to 6 treatment arms, we adjusted for multiple testing using a Bonferroni correction for up to 6 comparisons in each experiment. Under these assumptions, the minimum sample size for each

experiment is 5,858 subjects. Figures (6) to (9) in the appendix show that each experiment has a larger sample size than required.

7 Hypotheses

The principal set of hypotheses concerns the impact of behavioral-based text messages on the uptake of HPV vaccination. Specifically, we will evaluate each behavioral treatment's main hypotheses (M). In addition, as we have many behavioral treatments, we will also test a set of general hypotheses (G) and subgroups hypotheses (S). The final set of hypotheses is about heterogeneous effects exploration.

7.1 Hypotheses about altruism and warm-glow

Hypothesis M.1: Receiving a text message based on altruism or warm-glow insights positively affects HPV vaccination take-up.

Hypothesis S.1: Receiving a text message based on *any* altruism insights positively affects HPV vaccination take-up.

Hypothesis S.2: Receiving a text message based on *any* warm-glow insights (intrinsic or extrinsic) positively affects HPV vaccination take-up.

Hypothesis G.1: Receiving a text message based on *any* altruism or warm-glow insights positively affects HPV vaccination take-up.

7.2 Hypotheses about beliefs

Hypothesis M.2: Receiving a text message that seeks to correct beliefs regarding HPV positively affects HPV vaccination take-up.

Hypothesis G.2: Receiving *any* text message that seeks to correct beliefs regarding HPV positively affects HPV vaccination take-up.

7.3 Hypotheses about decision aids

Hypothesis M.3: Receiving a text message that relies on decision aids positively affects the uptake of HPV vaccination.

Hypothesis M.4: Receiving both a text message based on default options and one with milkman’s insight has a larger positive effect on HPV vaccination take-up than the individual effects of these treatments.

Hypothesis G.3: Receiving a text message based on *any* decision aids positively affects HPV vaccination take-up.

The above hypotheses are based on comparisons with the pure control group, the placebo control group, and the union of both control groups. We also consider an auxiliary hypothesis (A) related to the different control groups in our experimental designs:

Hypothesis A.1: There is no difference between receiving a placebo message (placebo control) and not receiving a message (pure control) in increasing HPV vaccination take-up.

7.4 Hypotheses about the Heterogeneity of Impacts

Due to the lack of covariates, we will not conduct sophisticated methods to analyze the heterogeneous effects. We will explore the heterogeneity of impacts on if the person belongs to the contributory or subsidized regime, access to health insurance, nationality, ethnicity, and displacement by civil war. The hypothesis is the following:

Hypothesis H.1: The individual characteristics of parents and daughters are likely to influence HPV vaccination take-up. We consider this hypothesis for each of the above features for any experiment.

8 Research Design

As described above, we applied three types of experiments and four in total, three for the sample of unvaccinated girls and one for girls with incomplete vaccination schedules. The experimental design for each treatment is presented in figures (6) through (9).

8.1 Outcomes

The primary outcome is a categorical variable that indicates whether a parent’s daughter is vaccinated against HPV during the SMS campaign window (6 weeks) or during the 6 weeks after the end of the intervention.

8.2 Randomization

The experiment employed a randomized block design. Specifically, participants were divided into blocks according to their location (Bogotá or outside Bogotá) and the girl’s age. Since we used age as a block variable, we constructed a binary variable to avoid the “curse of dimensionality .” This dummy variable equals 1 for girls aged 9 and 10 and 0 for the other cases. Participants were subsequently assigned to only one of the above behavioral experiments using the re-randomization algorithm suggested by Morgan and Rubin (2012).

Each experiment incorporates two control groups besides the behavioral treatment groups: the pure control group does not receive any message, and the placebo control receives a message about mental health care and contains the fixed elements. We intend to distinguish between the effect of sending a message and sending a behavioral-based text message with this placebo message. Figure 5 shows the content of the placebo control message.

Figure 5: SMS Content for placebo control

Placebo control

Hello Fransheska. Take care of your mental health. Exercise, meditate, eat well and get adequate sleep. Secretary of Health.

We sent weekly messages to the treatment sample for six weeks. The timeline of the experiment is presented in figure (1). Informed consent was not necessary for this project as it was implemented within the framework of the public policy of vaccination against HPV implemented by the health authorities of the District of Bogotá. In this scenario, the HS of the District of Bogotá already uses a communication campaign through text messages to encourage vaccination. The research team’s contribution was to design a communication strategy based on behavioral sciences to improve the strategy already implemented by the city’s health authorities. The IRB of the Universidad del Rosario approved this intervention.

8.3 Balance

Tables (3) to (6) report the analysis of the balance of randomization on the limited set of pre-treatment covariates for each experiment. These tables suggest that the randomization of the experiments ensured no difference between treatment arms in terms of observables.

9 Estimation Strategy

This section discusses the methods that will be employed to evaluate the impact of the SMS campaign on HPV vaccination take-up.

9.1 Estimation of Treatment Effects

We will estimate the impacts of interventions using an intention-to-treat (ITT) approach. We will estimate models as follows:

$$Y_{ij} = \alpha + \sum_{\kappa=1}^K \beta_{\kappa} Z_j + \theta_s + X'_{ij} \delta + \varepsilon_{ij} \quad (1)$$

Where Y_{ij} is the outcome of interest for girl i from parent j measured six weeks after the end of the SMS campaign. Z_j denotes the treatment status of parent j . θ_s is a vector

of randomization strata dummy variables (location*age). X'_{ij} is a vector of pre-treatment covariates at the girl and parent level, and ε_{ij} is the error term. β_κ is our parameter of interest that will capture the ITT effect for each treatment arm.

9.2 Heterogeneous Treatment Effects

We will test the differential impact of the treatments, including the interaction terms of the pre-treatment variables of interest W_j for parent j with the treatment variables. Then we will estimate models of the following form:

$$Y_{ij} = \alpha + \sum_{\kappa=1}^K \beta_\kappa Z_j + \gamma W_j + \sum_{\kappa=1}^K \varphi_\kappa (Z_j \cdot W_j) + \theta_s + X'_{ij} \delta + \varepsilon_{ij} \quad (2)$$

Where the coefficients φ_κ recover the heterogeneous treatment effects. The pre-treatment covariates of interest are contributory regime, subsidized regime, access to health insurance, nationality, ethnicity, and displacement by civil war. In addition, if we can obtain more features from administrative records. We will apply the generic machine learning strategy proposed by Chernozhukov et al. (2018).

9.3 Addressing Multiple Inference

Multiple hypothesis testing is a concern for our study because we have multiple treatment arms and pre-treatment characteristics to explore heterogeneities. Therefore, we will implement the Benjamini and Hochberg (1995) method to control the false discovery rate.

9.4 Non-compliance

Given the nature of our study, parents cannot change their treatment status. However, the fact that we send a message does not guarantee that it will be read, so ITT estimates will capture the effect of receiving a text message with behavioral components.

9.5 Attrition

Since we work with administrative records, attrition will not be a problem in our study. However, we could implement Lee (2009) if required.

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Tables

Table 1: Descriptive Statistics for Sample of Unvaccinated Girls

Variables	mean	sd	min	max	N
Girl's age in years	10.61	1.857	9	17	16,538
EPS Sanitas	0.0993	0.299	0	1	16,538
EPS Salud Total	0.0825	0.275	0	1	16,538
EPS Famisanar	0.150	0.357	0	1	16,538
EPS Compensar	0.117	0.321	0	1	16,538
EPS Capital Salud	0.0516	0.221	0	1	16,538
Other EPS	0.500	0.500	0	1	16,538
Contributory Scheme	0.693	0.461	0	1	16,538
Uninsured	0.0951	0.293	0	1	16,538
Subsidized Scheme	0.144	0.351	0	1	16,538
Other scheme	0.0680	0.252	0	1	16,538
Belongs to some ethnic group	0.00955	0.0973	0	1	16,538
Displaced by the armed conflict	0.0207	0.142	0	1	16,538
Colombian nationality	0.983	0.127	0	1	16,538

Table 2: Descriptive Statistics for the Sample of Girls with Incomplete Vaccination Schedules

Variables	mean	sd	min	max	N
Girl's age in years	11.25	2.013	9	17	5,907
EPS Sanitas	0.147	0.354	0	1	5,907
EPS Salud Total	0.101	0.301	0	1	5,907
EPS Famisanar	0.204	0.403	0	1	5,907
EPS Compensar	0.184	0.387	0	1	5,907
EPS Capital Salud	0.0963	0.295	0	1	5,907
Other EPS	0.268	0.443	0	1	5,907
Contributory Scheme	0.813	0.390	0	1	5,907
Uninsured	0.0130	0.113	0	1	5,907
Subsidized Scheme	0.123	0.328	0	1	5,907
Other scheme	0.0508	0.220	0	1	5,907
Belongs to some ethnic group	0.00508	0.0711	0	1	5,907
Displaced by the armed conflict	0.0124	0.110	0	1	5,907
Colombian nationality	0.963	0.189	0	1	5,907

Table 3: Randomization Balance Analysis. Experiment 1: Altruism and warm-glow

Variable	(1)	(2)	(3)	(4)	(5)	(6)	T-test Difference				
	Pure control Mean/SE	Placebo control Mean/SE	Altruism-soft Mean/SE	Altruism-strong Mean/SE	Warm-glow intrinsic Mean/SE	Warm-glow extrinsic Mean/SE	(1)-(2)	(1)-(3)	(1)-(4)	(1)-(5)	(1)-(6)
EPS Sanitas	0.099 (0.008)	0.090 (0.008)	0.105 (0.009)	0.104 (0.009)	0.109 (0.009)	0.100 (0.008)	0.009	-0.006	-0.005	-0.010	-0.001
EPS Salud Total	0.086 (0.008)	0.083 (0.008)	0.079 (0.008)	0.077 (0.007)	0.090 (0.008)	0.077 (0.007)	0.004	0.008	0.009	-0.003	0.009
EPS Famisanar	0.151 (0.010)	0.136 (0.010)	0.151 (0.010)	0.167 (0.010)	0.136 (0.010)	0.151 (0.010)	0.015	0.000	-0.016	0.015	0.000
EPS Compensar	0.114 (0.009)	0.119 (0.009)	0.123 (0.009)	0.103 (0.009)	0.108 (0.009)	0.119 (0.009)	-0.005	-0.009	0.011	0.006	-0.005
EPS Capital Salud	0.053 (0.006)	0.057 (0.006)	0.053 (0.006)	0.058 (0.007)	0.045 (0.006)	0.051 (0.006)	-0.003	0.001	-0.005	0.009	0.002
Other EPS	0.496 (0.014)	0.517 (0.014)	0.489 (0.014)	0.492 (0.014)	0.513 (0.014)	0.502 (0.014)	-0.020	0.007	0.004	-0.017	-0.006
Contributory Scheme	0.691 (0.013)	0.675 (0.013)	0.700 (0.013)	0.694 (0.013)	0.702 (0.013)	0.698 (0.013)	0.016	-0.009	-0.003	-0.011	-0.007
Uninsured	0.094 (0.008)	0.103 (0.009)	0.097 (0.008)	0.090 (0.008)	0.089 (0.008)	0.088 (0.008)	-0.009	-0.003	0.004	0.005	0.006
Subsidized Scheme	0.148 (0.010)	0.159 (0.010)	0.136 (0.010)	0.150 (0.010)	0.147 (0.010)	0.143 (0.010)	-0.011	0.012	-0.002	0.001	0.005
Other scheme	0.068 (0.007)	0.063 (0.007)	0.067 (0.007)	0.066 (0.007)	0.062 (0.007)	0.071 (0.007)	0.005	0.001	0.002	0.006	-0.003
Belongs to some ethnic group	0.008 (0.002)	0.011 (0.003)	0.010 (0.003)	0.005 (0.002)	0.013 (0.003)	0.010 (0.003)	-0.003	-0.002	0.003	-0.006	-0.002
Displaced by the armed conflict	0.024 (0.004)	0.026 (0.004)	0.024 (0.004)	0.015 (0.003)	0.017 (0.004)	0.017 (0.004)	-0.002	0.001	0.009*	0.008	0.008
Colombian nationality	0.986 (0.003)	0.986 (0.003)	0.984 (0.003)	0.985 (0.003)	0.980 (0.004)	0.985 (0.003)	0.000	0.002	0.001	0.006	0.001
Girl's age in years	10.586 (0.052)	10.623 (0.052)	10.615 (0.052)	10.570 (0.050)	10.627 (0.052)	10.619 (0.053)	-0.036	-0.028	0.016	-0.040	-0.033
N	1272	1272	1272	1273	1272	1272					

Notes: The value displayed for t-tests are the differences in the means across the groups. ***, **, and * indicate significance at the 1, 5, and 10 percent critical level.

Table 4: Randomization Balance Analysis. Experiment 2: Beliefs

Variable	(1)	(2)	(3)	(4)	(5)	T-test		
	Pure control Mean/SE	Placebo control Mean/SE	Beliefs general (video) Mean/SE	Beliefs vaccination timing Mean/SE	Beliefs severity global Mean/SE	(1)-(2)	(1)-(3)	(1)-(4)
EPS Sanitas	0.099 (0.008)	0.090 (0.008)	0.096 (0.008)	0.089 (0.008)	0.093 (0.008)	0.009	0.003	0.010
EPS Salud Total	0.086 (0.008)	0.083 (0.008)	0.083 (0.008)	0.094 (0.008)	0.080 (0.008)	0.004	0.003	-0.008
EPS Famisanar	0.151 (0.010)	0.136 (0.010)	0.155 (0.010)	0.150 (0.010)	0.145 (0.010)	0.015	-0.004	0.001
EPS Compensar	0.114 (0.009)	0.119 (0.009)	0.113 (0.009)	0.108 (0.009)	0.132 (0.009)	-0.005	0.001	0.006
EPS Capital Salud	0.053 (0.006)	0.057 (0.006)	0.047 (0.006)	0.053 (0.006)	0.050 (0.006)	-0.003	0.006	0.001
Other EPS	0.496 (0.014)	0.517 (0.014)	0.506 (0.014)	0.506 (0.014)	0.501 (0.014)	-0.020	-0.009	-0.010
Contributory Scheme	0.691 (0.013)	0.675 (0.013)	0.691 (0.013)	0.672 (0.013)	0.692 (0.013)	0.016	0.000	0.019
Uninsured	0.094 (0.008)	0.103 (0.009)	0.095 (0.008)	0.100 (0.008)	0.101 (0.008)	-0.009	-0.002	-0.006
Subsidized Scheme	0.148 (0.010)	0.159 (0.010)	0.134 (0.010)	0.150 (0.010)	0.145 (0.010)	-0.011	0.013	-0.002
Other scheme	0.068 (0.007)	0.063 (0.007)	0.079 (0.008)	0.078 (0.008)	0.062 (0.007)	0.005	-0.012	-0.010
Belongs to some ethnic group	0.008 (0.002)	0.011 (0.003)	0.009 (0.003)	0.009 (0.003)	0.010 (0.003)	-0.003	-0.001	-0.001
Displaced by the armed conflict	0.024 (0.004)	0.026 (0.004)	0.017 (0.004)	0.022 (0.004)	0.021 (0.004)	-0.002	0.008	0.002
Colombian nationality	0.986 (0.003)	0.986 (0.003)	0.987 (0.003)	0.980 (0.004)	0.981 (0.004)	0.000	-0.001	0.006
Girl's age in years	10.586 (0.052)	10.623 (0.052)	10.512 (0.049)	10.639 (0.054)	10.583 (0.051)	-0.036	0.075	-0.053
N	1272	1272	1272	1273	1272			

Notes: The value displayed for t-tests are the differences in the means across the groups. ***, **, and * indicate significance at the 1, 5, and 10 percent critical level.

Table 5: Randomization Balance Analysis. Experiment 3: Decision aids (unvaccinated girls)

Variable	(1)	(2)	(3)	(4)	(5)	(6)	T-test				
	Pure control Mean/SE	Placebo control Mean/SE	Milkman's insight Mean/SE	Soft-default Mean/SE	Version 1 Mean/SE	Version 2 Mean/SE	(1)-(2)	(1)-(3)	(1)-(4)	(1)-(5)	(1)-(6)
EPS Sanitas	0.099 (0.008)	0.090 (0.008)	0.105 (0.009)	0.106 (0.009)	0.099 (0.008)	0.097 (0.008)	0.009	-0.006	-0.007	0.000	0.002
EPS Salud Total	0.086 (0.008)	0.083 (0.008)	0.090 (0.008)	0.068 (0.007)	0.083 (0.008)	0.083 (0.008)	0.004	-0.003	0.019*	0.004	0.003
EPS Famisanar	0.151 (0.010)	0.136 (0.010)	0.138 (0.010)	0.153 (0.010)	0.160 (0.010)	0.160 (0.010)	0.015	0.012	-0.002	-0.009	-0.009
EPS Compensar	0.114 (0.009)	0.119 (0.009)	0.112 (0.009)	0.126 (0.009)	0.119 (0.009)	0.123 (0.009)	-0.005	0.002	-0.012	-0.006	-0.009
EPS Capital Salud	0.053 (0.006)	0.057 (0.006)	0.055 (0.006)	0.058 (0.007)	0.050 (0.006)	0.042 (0.006)	-0.003	-0.002	-0.005	0.004	0.012
Other EPS	0.496 (0.014)	0.517 (0.014)	0.500 (0.014)	0.489 (0.014)	0.490 (0.014)	0.495 (0.014)	-0.020	-0.004	0.007	0.006	0.001
Contributory Scheme	0.691 (0.013)	0.675 (0.013)	0.700 (0.013)	0.690 (0.013)	0.697 (0.013)	0.702 (0.013)	0.016	-0.009	0.001	-0.006	-0.011
Uninsured	0.094 (0.008)	0.103 (0.009)	0.098 (0.008)	0.086 (0.008)	0.098 (0.008)	0.099 (0.008)	-0.009	-0.004	0.007	-0.005	-0.006
Subsidized Scheme	0.148 (0.010)	0.159 (0.010)	0.139 (0.010)	0.159 (0.010)	0.138 (0.010)	0.125 (0.009)	-0.011	0.009	-0.011	0.009	0.023*
Other scheme	0.068 (0.007)	0.063 (0.007)	0.063 (0.007)	0.064 (0.007)	0.067 (0.007)	0.074 (0.007)	0.005	0.005	0.003	0.001	-0.006
Belongs to some ethnic group	0.008 (0.002)	0.011 (0.003)	0.008 (0.002)	0.011 (0.003)	0.013 (0.003)	0.007 (0.002)	-0.003	-0.000	-0.003	-0.006	0.001
Displaced by the armed conflict	0.024 (0.004)	0.026 (0.004)	0.022 (0.004)	0.021 (0.004)	0.026 (0.004)	0.018 (0.004)	-0.002	0.002	0.003	-0.002	0.006
Colombian nationality	0.986 (0.003)	0.986 (0.003)	0.981 (0.004)	0.978 (0.004)	0.983 (0.004)	0.989 (0.003)	0.000	0.005	0.008	0.002	-0.003
Girl's age in years	10.586 (0.052)	10.623 (0.052)	10.582 (0.050)	10.639 (0.053)	10.659 (0.055)	10.621 (0.053)	-0.036	0.004	-0.052	-0.072	-0.035
N	1272	1272	1271	1273	1272	1272					

Notes: The value displayed for t-tests are the differences in the means across the groups. ***, **, and * indicate significance at the 1, 5, and 10 percent critical level.

Table 6: Randomization Balance Analysis. Experiment 3: Decision aids (girls with incomplete vaccination schedules)

Variable	(1)	(2)	(3)	(4)	(5)	(6)	T-test				
	Pure Control Mean/SE	Placebo Control Mean/SE	Milkman's insight Mean/SE	Soft-default Mean/SE	Version 1 Mean/SE	Version 2 Mean/SE	(1)-(2)	(1)-(3)	(1)-(4)	(1)-(5)	(1)-(6)
EPS Sanitas	0.144 (0.011)	0.131 (0.011)	0.145 (0.011)	0.152 (0.011)	0.153 (0.011)	0.158 (0.012)	0.013	-0.001	-0.008	-0.009	-0.013
EPS Salud Total	0.092 (0.009)	0.105 (0.010)	0.100 (0.010)	0.098 (0.009)	0.108 (0.010)	0.104 (0.010)	-0.012	-0.007	-0.006	-0.015	-0.011
EPS Famisanar	0.216 (0.013)	0.202 (0.013)	0.215 (0.013)	0.194 (0.013)	0.203 (0.013)	0.193 (0.013)	0.014	0.002	0.023	0.013	0.023
EPS Compensar	0.180 (0.012)	0.183 (0.012)	0.195 (0.013)	0.185 (0.012)	0.172 (0.012)	0.188 (0.012)	-0.003	-0.016	-0.005	0.008	-0.008
EPS Capital Salud	0.095 (0.009)	0.101 (0.010)	0.083 (0.009)	0.102 (0.010)	0.102 (0.010)	0.095 (0.009)	-0.005	0.012	-0.007	-0.006	0.001
Other EPS	0.272 (0.014)	0.279 (0.014)	0.261 (0.014)	0.269 (0.014)	0.262 (0.014)	0.263 (0.014)	-0.007	0.011	0.003	0.010	0.009
Contributory Scheme	0.827 (0.012)	0.801 (0.013)	0.815 (0.012)	0.810 (0.012)	0.814 (0.012)	0.812 (0.012)	0.026	0.013	0.017	0.013	0.015
Uninsured	0.012 (0.003)	0.012 (0.003)	0.015 (0.004)	0.015 (0.004)	0.011 (0.003)	0.012 (0.004)	0.000	-0.003	-0.003	0.001	-0.000
Subsidized Scheme	0.112 (0.010)	0.131 (0.011)	0.115 (0.010)	0.129 (0.011)	0.126 (0.011)	0.125 (0.011)	-0.019	-0.003	-0.017	-0.014	-0.013
Other scheme	0.049 (0.007)	0.056 (0.007)	0.055 (0.007)	0.046 (0.007)	0.049 (0.007)	0.051 (0.007)	-0.007	-0.006	0.003	-0.000	-0.002
Belongs to some ethnic group	0.002 (0.001)	0.005 (0.002)	0.006 (0.002)	0.007 (0.003)	0.003 (0.002)	0.007 (0.003)	-0.003	-0.004	-0.005*	-0.001	-0.005*
Displaced by the armed conflict	0.012 (0.003)	0.010 (0.003)	0.015 (0.004)	0.010 (0.003)	0.008 (0.003)	0.018 (0.004)	0.002	-0.003	0.002	0.004	-0.006
Colombian nationality	0.969 (0.006)	0.959 (0.006)	0.957 (0.006)	0.963 (0.006)	0.966 (0.006)	0.961 (0.006)	0.009	0.011	0.005	0.002	0.007
Girl's age in years	11.237 (0.064)	11.278 (0.065)	11.243 (0.063)	11.217 (0.063)	11.275 (0.065)	11.264 (0.065)	-0.042	-0.007	0.020	-0.039	-0.028
N	985	985	983	986	984	984					

Notes: The value displayed for t-tests are the differences in the means across the groups. ***, **, and * indicate significance at the 1, 5, and 10 percent critical level.

Figures

Figure 6: Experimental Design for experiment 1: Altruism and warm-glow

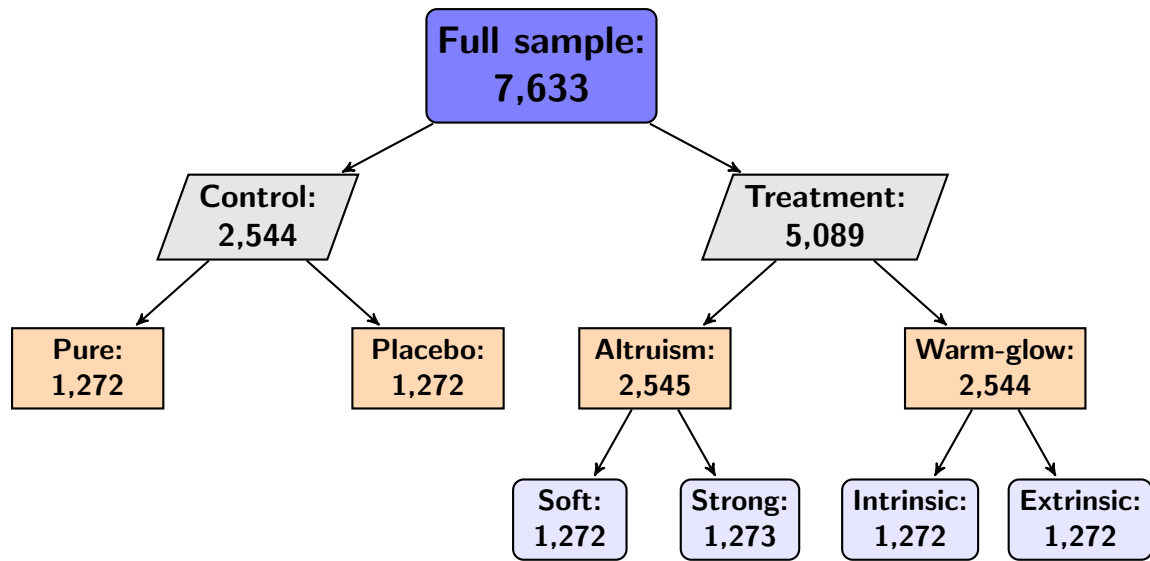


Figure 7: Experimental Design experiment for experiment 2: Beliefs

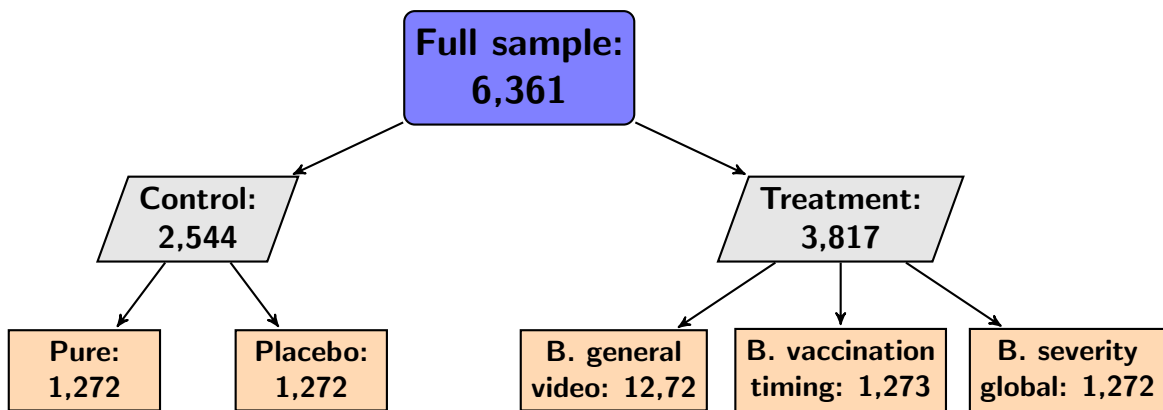


Figure 8: Experimental Design for experiment 3: Decision aids (unvaccinated girls)

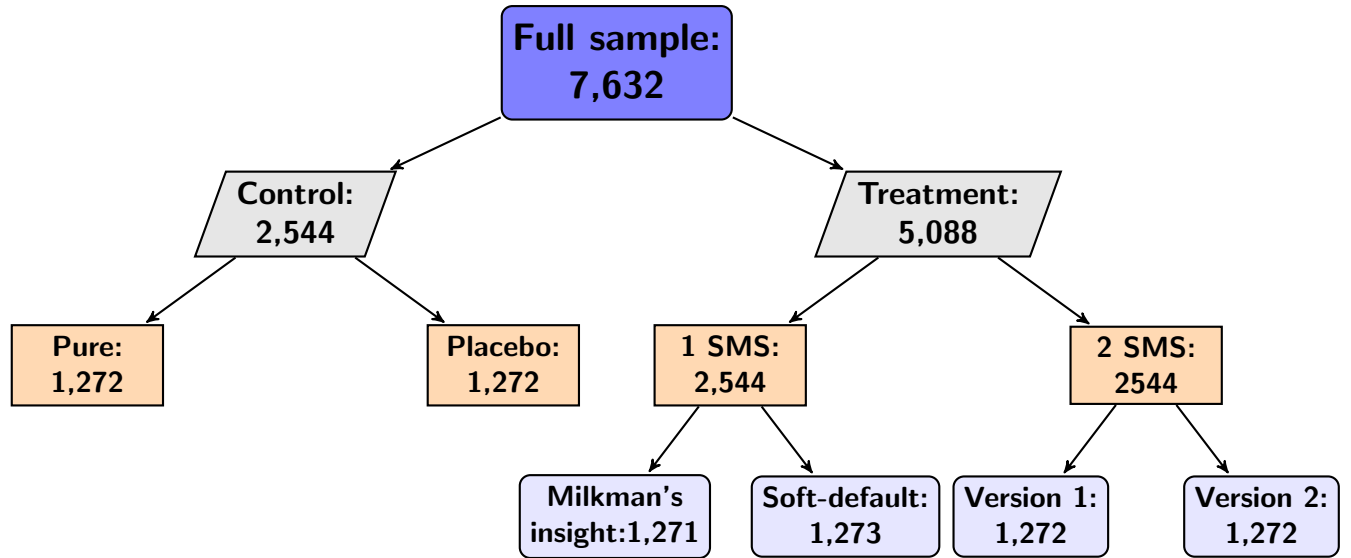


Figure 9: Experimental Design for experiment 4: Decision aids (incomplete schedules)

