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Improving childhood immunization through maternal support: Evidence from a randomized intervention in Pakistan☆,☆☆

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ABSTRACT

We evaluate the effectiveness of randomized interventions aimed at alleviating behavioral barriers — such as maternal stress and psychological strain, limited future-oriented thinking, and information frictions — for early childhood immunization uptake in a sample of Pakistani mothers with infants. A phone-delivered intervention providing light psychological support as well as visualization and planning techniques increases the total number of vaccines received by young children by 0.3, or 7% of the control mean, one year after baseline. We also find that the intervention improves maternal knowledge, attitudes, and perceived returns to vaccination. However, supplementing this intervention with vaccination-related information from influencers does not yield additional benefits in this context.

1. Introduction

Immunization is a highly successful and cost-effective public health intervention. However, only half of Pakistani children receive all their basic vaccinations by their second birthday (PDHS, 2019). Due to this lack of vaccination coverage, many preventable infectious diseases, including polio, are endemic to Pakistan. While supply-side challenges contribute to this issue, a significant barrier lies in low demand for immunization. The dominant explanation for low take-up in this context centers on a lack of understanding about the health benefits of vaccines, biased perceptions, and conspiracy theories. However, many households also face substantial psychological constraints, such as stress, poor mental health, and a tendency to prioritize immediate needs over long-term benefits. Even absent information frictions, these households may be unable to take on costly actions that lead to long-term gains.

Building on the latter set of explanations and insights from our focus groups, where we found that most households in our study area expect some benefits of vaccinations, we design and evaluate interventions targeting behavioral barriers — such as maternal stress and psychological strain, limited future-oriented thinking, and information frictions — that may affect the demand for early childhood immunizations through a randomized controlled trial (RCT) in Pakistan with 2145 mothers. Specifically, we design two interventions delivered over the phone to mothers with a child under the age of five months in rural areas. The first intervention combines light psychological support with guided visualization and planning exercises to help mothers overcome psychological barriers to immunization. The visualization component emphasizes the short- and long-term benefits of immunizations by asking mothers to picture two states of the world—one where they immunize their child and one where they do not. The planning

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component supports mothers in translating intentions into concrete, actionable steps. We denote this intervention as a psychological first aid (PFA), acknowledging that it bundles multiple components. The second intervention, the Influencers treatment, delivers audio recordings of prominent members of the community (a government official, a doctor, a religious figure and a pro-vaccination mother), who explain the benefits of early childhood immunization and address common myths related to vaccines. All calls were delivered using a standardized, scripted protocol, and counselors received dedicated training in the use of this script to ensure consistency and fidelity in implementation. One group of participants received the PFA, while another group received both treatments (PFA + Influencers). Both treatment groups also received SMS reminders about when to immunize their child. A third control group received no intervention.

Our evaluation of the treatment effect is based on the 1057 mothers who completed the endline survey. One year after our baseline data collection, we find a positive and precisely estimated impact of the PFA on the total number of vaccines administered to the child. Children whose mothers were exposed to the PFA received, on average, an additional 0.3 vaccines relative to a control mean of 4.42, reflecting a 7% increase. The magnitude of the treatment effect is larger for vaccines that are more likely to be missed. For instance, treated children exhibit an 8.9 percentage point increase in the likelihood of receiving the pentavalent vaccine, administered to only 53% of the control children. We also find a 7.4 percentage point increase in the likelihood of receiving vaccines within the recommended schedule (the control mean is 39%). Importantly, we find no additional impact of the Influencers treatment on the total number of vaccines or any individual vaccines. In fact, the Influencers treatment mutes the impacts of the PFA.

We further examine heterogeneity in treatment effects to shed light on which households benefit most from the intervention. The impacts are higher among low-income households and among mothers with less optimistic baseline expectations about the benefits of vaccination. The treatment appears particularly effective for mothers with higher levels of self-efficacy, especially for on-time vaccination, consistent with the idea that psychological support, visualization, and planning techniques are most powerful when mothers feel able to act on their intentions. Finally, we find suggestive evidence that mothers with intermediate levels of baseline mental health benefit the most, whereas those in very good or very poor mental health benefit less.

It is worth noting that the PFA did not have a noticeable impact on maternal mental health, as measured by the PHQ-9 score. However, PFA-treated mothers demonstrated enhanced vaccination knowledge, reflected in a 2.7% increase in a knowledge index compared to the control mean. Additionally, they expressed a greater belief in the efficacy of vaccinations in preventing childhood diseases, with an effect size equivalent to 29% of the mean of the untreated counterparts. Moreover, we observe a 17% standard deviation increase in our index of expectations, which measures beliefs about how vaccinating a child may impact outcomes such as health, schooling, and earnings. Collectively, these findings suggest that the PFA intervention fostered greater engagement with the vaccination process and the broader healthcare system among treated mothers.

Notably, the Influencers treatment mutes this increase in the knowledge score and in the expectations index. This is important and suggests that (1) PFA-treated mothers were actively motivated to *seek out* and *acquire* pertinent vaccination-related information, and (2) messages from influencers, in a setting where there is distrust about vaccinations and little confidence in authorities, actually made the PFA treatment less effective. This finding underscores the potential pitfalls of introducing external messages in settings with significant conspiracy theories. By contrast, relaxing psychological constraints through light-touch support and visualization and planning techniques appear to facilitate more effective information search and retention. Supporting this interpretation, we find no significant treatment effect on mothers' willingness to pay (WTP) for immunization phone reminders at endline, suggesting that the PFA intervention's impact operated through enhanced internal motivation rather than external reinforcements.

Our intervention was motivated by three strands of research. The first has shown that short and cost-effective interventions can have a significant impact on common mental health issues (Singla et al., 2017), including in South Asia (Rahman et al., 2019; Vlassopoulos et al., 2023; Bhat et al., 2022).[1] This is relevant because mental health support to mothers improves children's outcomes (Baranov et al., 2020a). The second body of research has investigated the effectiveness of simple psychological interventions that encourage participants to visualize different states of the future. In the context of demand for preventive health products (water chlorination), John and Orkin (2022) show that encouraging individuals to visualize alternate realizations of the future leads to better outcomes, by increasing self-efficacy and individuals' skill in forecasting their future utility.[2] A third strand of literature shows that information interventions can address misperceptions and promote health-seeking behaviors (Dupas, 2011), though effectiveness varies by delivery method and cultural context. In Pakistan, generic interventions on immunization rates show mixed results (Owais et al., 2011; Usman et al., 2011). However, it is worth noting that tailoring to local norms and using persuasive techniques like moral messaging or celebrity endorsements has been found to enhance impact (Delavande and Zafar, 2018; Bursztyn et al., 2019; Masoud et al., 2016).

Our findings contribute to understanding the root causes of the low uptake of preventative health measures in low-income countries (e.g., Dupas and Miguel 2017, Kremer et al. 2019), specifically examining the roles of information frictions and behavioral barriers, including psychological strain and future-oriented thinking. In recent years, there has been growing interest in the use of "nudges" to encourage immunization uptake, which involves *external* motivators such as small incentives in cash or kind, SMS reminders, and endorsements from influential individuals (e.g., Banerjee and Mullainathan 2010, Domek et al. 2016, Alatas et al. 2019, Banerjee et al. 2024). These strategies have been tested in various settings and have shown positive impacts on take-up of immunization.

Our intervention differs by addressing *internal* motivators, such as psychological barriers, that can hinder uptake. Our findings indicate that leveraging internal factors can be effective in promoting vaccinations. Previous research has also explored social signaling as an internal motivator for childhood immunization (Karing, 2024), demonstrating its effectiveness, but its impact may vary across contexts. In settings where vaccinations may carry negative connotations — as in our context (Martinez-Bravo and Stegmann, 2022) — social signaling could be ineffective or even counterproductive. One key advantage of targeting internal motivators is the potential for sustained effects, even after the treatment ends, with positive spillovers to areas like improved knowledge and possibly to other siblings. Here, it is apparent in the positive treatment effect on vaccination knowledge and expectations in the PFA treatment group. Information interventions are not always effective, but our results indicate that creating demand for information — rather than merely providing it — can significantly improve knowledge. Furthermore, our findings emphasize that activating internal motivation may reduce reliance on external incentives.

[1] However, not all interventions are effective in all contexts (Baranov et al., 2020b).

[2] Likewise, Ashraf et al. (2024) find that an imagery-based entrepreneurial training program leads to significantly better economic outcomes (relative to a traditional business skills training program) in a randomized controlled trial of would-be entrepreneurs in Colombia.

2. Background

Childhood immunization rates in Pakistan are alarmingly low: nearly one-third of children between 12–23 months of age have not received basic vaccinations, representing approximately 15.1 million children below the age of 4 (PDHS, 2019). On-time vaccination is also problematic: nearly half of children in this age group do not receive vaccinations on schedule. Regional disparities are stark, with only 37% of children in Khyber Pakhtunkhwa (KP) and 23% in the Federally Administered Tribal Area (FATA) fully vaccinated, compared to 66% in Punjab (PDHS, 2019). There is also a socioeconomic gradient, with vaccination rates substantially lower among children from households where mothers have no education compared to those where mothers have some post-secondary education (PDHS, 2019).

Pakistan's immunization efforts are implemented through the Expanded Programme on Immunization (EPI), a national, government-run initiative launched in 1978 with support from WHO and UNICEF. The EPI provides free routine vaccines across Pakistan against major vaccine-preventable diseases for children under 24 months of age, delivered through fixed health facilities and outreach services. Table F1 presents the EPI vaccination schedule. Despite being a long-established program, routine immunization coverage remains inconsistent across districts, constrained by gaps in outreach, logistics, staffing, and data systems (Masud and Navaratne, 2019).

As a consequence of these persistent gaps, Pakistan remains one of the three countries in the world where polio is still endemic (WHO, 2015). Measles outbreaks have similarly surged, and other diseases like diphtheria, pertussis, and rubella have seen significant increases (WHO, 2018).

In addition, misperceptions about vaccines, such as fears about contamination and religious prohibitions, have fueled vaccine hesitancy. These fears worsened after the CIA's use of a fake vaccination campaign during the hunt for Osama bin Laden (Roul, 2014). Extremist groups capitalized on the incident, spreading rumors that polio vaccines contained harmful substances. This misinformation has significantly harmed vaccination efforts (Martinez-Bravo and Stegmann, 2022).

Also relevant to our study is the widespread prevalence of maternal depression in Pakistan. Globally, maternal depression affects approximately 10–20% of women during pregnancy and in the first year after childbirth (Dadi et al., 2020). In Pakistan, evidence suggests that perinatal depression affects around a quarter of women (Baranov et al., 2020a). The condition is associated with severe and long-lasting effects on both the mother and the child, including increased risk of low birth weight, impaired cognitive development, and difficulties in bonding and attachment. Factors that contribute to this high prevalence include poverty, low educational levels, lack of social support, gender-based violence, and cultural norms that stigmatize mental health issues. Despite its significant burden, maternal depression continues to be under-diagnosed and under-treated (Gelaye et al., 2016).

3. Research design and intervention

3.1. Research design

The study design is a randomized controlled trial (RCT) conducted in Abbottabad and Swabi districts of KP province in Pakistan. The trial involved 2145 participants divided into three groups: a control group, a treatment group that receives the Influencers treatment and the psychological first aid (PFA), and a treatment group that receives the PFA only. Due to budgetary considerations, we did not have an arm where participants receive the Influencers treatment alone. We chose to target mothers (instead of fathers), based on focus group interviews that revealed that mothers tend to be the main decision-makers in the household regarding health investments in their children.[3]

The recruitment of participants, as well as the surveys, was done by Gallup Pakistan in 2022. The baseline survey was carried out face-to-face, while two follow-up surveys were conducted over the phone, with the final follow-up approximately one year after the baseline.

The intervention was designed in collaboration with Interactive Research & Development (IRD), Pakistan, which also managed its delivery. IRD is a health delivery and research organization committed to saving lives through improvements in global health. The interventions were delivered over the phone by counselors who had been rigorously recruited and trained. Ten counselors were hired, all based in Karachi, with at least a high school degree and prior experience in public or community mental health. They completed a structured six-day basic counseling skills training delivered by qualified psychologists, as well as a one-day immunization training to ensure consistency in responses to participants' questions. A final training module covered the standardized call scripts used in the intervention (see Appendix A.1 for further details on the recruitment and training of the counselors).

Although the decision for phone delivery was made due to the COVID pandemic, this approach is cost-effective and means that these interventions could be rolled out at scale. Appendix Figure F1 shows the study flowchart.

All children in our study accessed immunization services through the existing government system (EPI), and the intervention operated entirely on the demand side.

3.2. Intervention

The intervention consisted of three phone calls. Participants in the PFA Treatment group received two calls: Call 1 and Call 3, with a minimum gap of three weeks between the calls. Meanwhile, participants in the PFA + Information Treatment group received all three calls: Call 1, Call 2, and Call 3. For this group, there was a minimum gap of one week between each call. Each call lasted 20–30 min, followed by a check-in during which respondents could share their feelings.

All calls were delivered using a standardized, scripted protocol, and counselors received dedicated training in the use of this script to ensure consistency and fidelity across respondents. The full script is provided in Appendix A.2. To maintain uniformity in delivery, each counselor was assigned to a single treatment arm throughout the intervention. In addition, at the end of each call, participants were provided with a toll-free mental health helpline number in case they needed to speak with a professional. The control group received a short check-in phone call between the baseline and midline surveys to keep those respondents engaged with the study.

Call 1 (Both treatment groups)

The primary goal of Call 1 was to provide foundational support to both intervention groups and to create a safe space for conversation, establish trust, and conduct history-taking for brief psychological support. The call began by building trust between the counselor and respondent, with an emphasis on confidentiality. Once rapport was established, the counselor introduced mental health by asking open-ended questions about the respondent's overall health, linking maternal mental and physical well-being. The counselor conducted thorough history-taking, focusing on the mother's daily routine, income, housing, and family relationships. When mothers mentioned challenges, the counselor encouraged them to explore which strategies had helped, allowing for a deeper understanding of the underlying issues. Conversely, when mothers highlighted positive aspects of their lives, the counselor prompted them to reflect on the factors that kept them motivated

[3] It is generally the case that the father or some other male takes the child for vaccinations, but the mother tends to make the decision of whether the child will receive vaccines.

and supported, helping to identify key enablers. Toward the end, the counselor inquired about the baby's health, including hospital visits, emergencies, and immunization experiences. The call concluded by informing the respondent that gaining a better understanding of her daily challenges and supports could positively impact her child's health, particularly in relation to practices like immunization. This helped to naturally bridge to topics of immunization in the subsequent call(s).

Call 2 (PFA + Influencers group only)

The primary aim of Call 2 was to provide participants in the PFA + Influencers group with additional information to encourage childhood immunizations. The counselor played four brief pre-recorded audio messages in the respondent's local language, featuring a government official, a doctor, a religious figure, and a pro-vaccination mother. After each audio message, the counselor asked the mothers to summarize the key messages to ensure understanding and encouraged them to share their thoughts and feelings about the information they received. These messages highlighted the government's free vaccination program, the importance of preventing infectious diseases from a religious perspective, and addressed common myths and misinformation. They also emphasized the safety of vaccines and their mild side effects, contrasting these with the far greater financial and emotional costs of not vaccinating. See Appendix A.2.3 for the script of the audio recording.

Call 3 (Both treatment groups)

The objective of the call was to discuss immunizations, building on the personal history provided in Call 1 (and Call 2 for the PFA+ Information group). Two psychological techniques, *visualization* and *planning*, were employed. First, mothers were asked to visualize both outcomes: immunizing and not immunizing their child. They imagined saving money for medical needs and the relief it would bring, versus spending money and facing hardship when their child was sick. This introduced the concept of short-term benefits versus long-term planning. Next, mothers were prompted to visualize the process of immunizing their child and to imagine a future where a neighbor's unvaccinated child became seriously ill. They reflected on their feelings in both scenarios: having vaccinated their child or being in the neighbor's situation. The aim of the exercise was to emphasize the long-term benefits of immunization over immediate concerns about side effects. Following visualization, the planning technique had mothers create actionable steps, outlining when and where to vaccinate their child and identifying any logistical challenges. To reinforce this, mothers were encouraged to anticipate and troubleshoot potential barriers they might face on vaccination day.

In addition to the calls, participants in both treatment groups received a text message reminder the week before their child's vaccination was due (inferred from the child's age in weeks).

Respondents were incentivized to participate in the survey and treatment calls with a gift (for the baseline survey) or a phone airtime top-up on their phone (for the subsequent surveys and calls). Appendix Table F2 provides details of the incentives provided for each treatment.

3.3. Discussion—Theory of change

In this section, we provide theoretical underpinnings for the interventions. Low uptake of preventive health measures in low-income countries is pervasive and is often attributed to present bias and distorted beliefs about health benefits (e.g., Dupas and Miguel 2017, Kremer et al. 2019). Stress and poor mental health can further exacerbate these challenges by reducing cognitive bandwidth, impairing information processing, and limiting future-oriented decision-making. Guided by these insights, our intervention targets three interconnected barriers to childhood immunization: (i) limited future-oriented thinking, (ii) information frictions, and (iii) stress and psychological strain, which may directly reduce preventive health behaviors and indirectly do so by worsening both (i) and (ii).

Stress, poor mental health, and limited cognitive bandwidth. As discussed earlier, mothers in Pakistan often face substantial emotional strain stemming from perinatal depression as well as caregiving demands, economic constraints, and household responsibilities. Stress and poor mental health reduce the cognitive bandwidth available for weighing long-term benefits against short-term concerns. Evidence shows that poverty-related stress impedes cognitive function, undermines self-control, and can induce present bias (Mani et al., 2013; Bernheim et al., 2015; Carvalho et al., 2016). Because immunization requires incurring immediate costs for benefits that are delayed and partly abstract, bandwidth constraints can tilt decisions toward inaction even when mothers value child health. Stress and poor mental health may also impair information processing, leading to biased or incomplete belief updating (Korn et al., 2014).

Call 1 was designed to ease these psychological frictions. Counselors provided space to discuss daily challenges, validate feelings, and identify sources of support. This light-touch psychological support aims to modestly reduce mental strain and free up cognitive bandwidth, enabling mothers to engage with preventive actions and new information with greater focus and emotional clarity.

Information frictions. Beliefs about vaccines may be shaped by conflicting messages from family members, community narratives, or local authorities. When benefits are uncertain or misunderstood, intentions to vaccinate remain weak. The Influencers component (call 2) directly targets this barrier by delivering concise messages from trusted figures that reinforce vaccine safety, effectiveness, and religious permissibility. These messages aim to correct misconceptions that might otherwise suppress demand for immunization.

Future-oriented thinking and planning. Even when mothers hold positive beliefs about vaccination and intend to immunize, they may struggle to follow through. Motivation alone may be insufficient to translate intentions into actions; specific, feasible plans can help bridge this gap (Milkman et al., 2011). Existing work — including visualization interventions such as John and Orkin (2022) — shows that prompting individuals to imagine alternative future outcomes can strengthen future-oriented motivation by making distant consequences more vivid and emotionally salient. Visualization can therefore help counteract the tendency to overweight short-term burdens relative to long-term benefits.

Call 3, accordingly, combines a visualization exercise, designed to enhance future-oriented thinking, with structured action planning to facilitate follow-through. SMS reminders delivered to all treatment groups complement this process by reinforcing plans at the appropriate times.

4. Data

4.1. Recruitment and sample

We conducted participant recruitment for this study in the KP province of Pakistan through Gallup Pakistan. Our decision to focus on KP was motivated by the province's alarmingly low vaccination rates (see Section 2). Recruitment took place in two districts—Abbottabad and Swabi, with 43% of respondents recruited from Abbottabad. These districts were selected to reflect the substantial social, linguistic, and infrastructural diversity within KP: Swabi is predominantly rural, has low literacy, and is Pashto-speaking, with limited health infrastructure, while Abbottabad is more urbanized, has higher literacy, and is Hindko-speaking, with comparatively strong service provision.

The recruitment period spanned from March to October 2022. Eligibility criteria for participation in the study included being a mother with a child under the age of five months, providing oral informed consent, and having access to a phone during weekdays and weekends. Because mothers with newborns can be difficult to identify in the community, recruitment relied on two complementary channels: (a) community-based Lady Health Workers (LHWs), who shared the names

Table 1
Baseline characteristics.

	Sample means				*Normalized differences*	
	All	Control group	PFA only	PFA and influencers	PFA only	PFA and influencers
Observations	2145	760	688	697		
Panel A: *Demographics*						
Mother's age	28.09	28.32	28.12	27.79	−0.044	−0.111
Mother has primary schooling or less	0.34	0.33	0.35	0.35	0.033	0.045
Mother has secondary schooling	0.37	0.39	0.35	0.37	−0.087	−0.039
Father has primary schooling or less	0.17	0.14	0.18	0.20	0.108	0.149
Father has secondary schooling	0.36	0.37	0.37	0.34	0.002	−0.071
High income	0.40	0.40	0.39	0.41	−0.027	0.013
Rural	0.63	0.64	0.62	0.62	−0.036	−0.041
Number of children	2.62	2.62	2.61	2.62	−0.008	0.002
Age of index child (weeks)	10.41	10.61	10.64	9.96	0.005	−0.106
Index child female	0.46	0.47	0.48	0.43	0.022	−0.062
Panel B: *Vaccination*						
Total vaccines	3.47	3.39	3.62	3.42	0.113	0.013
On-time vaccination	0.34	0.32	0.36	0.33	0.086	0.031
Panel C: *Mental health, knowledge, and expectations*						
PHQ-9	9.29	9.49	9.28	9.07	−0.035	−0.071
Depressed (PHQ-9 ≥ 10)	0.41	0.43	0.41	0.40	−0.036	−0.061
Knowledge score	2.55	2.53	2.58	2.54	0.084	0.017
Exp. disease (all vac - no vac)	6.84	4.68	7.05	8.99	0.052	0.096
Exp. schooling (all vac - no vac)	5.44	5.24	5.84	5.25	0.154	0.001
Exp. log earnings (all vac - no vac)	0.89	0.88	0.91	0.89	0.054	0.016

Note: $N = 2145$ for all variables except schooling and log earnings expectations ($N = 2091$ and $N = 1763$, respectively). The normalized difference in a variable is the baseline difference between treatment and control means, divided by the pooled standard deviation (the square root of half the control-group variance plus half the treatment-group variance). Imbens and Wooldridge (2009) suggest the heuristic that normalized differences with absolute value less than 0.25 indicate sufficient balance.
The mother's mental health is measured by the PHQ-9 index, which is based on the responses to nine questions. A higher PHQ-9 score corresponds to worse mental health.
The mother's knowledge score is based on four questions about the number and timing of vaccinations. It ranges from zero if the mother answered none of the questions correctly, to four if the mother answered all four questions correctly. The knowledge questions are "How many visits for vaccine does a baby need to have in the first 15 months to get all the recommended vaccines?", "Does the baby need to receive vaccines at birth?", "Does the baby need to receive vaccines at 6 weeks?", and "Does the baby need to receive vaccines at 6 months?".
Mothers were asked the probability their child would get any serious side effects in childhood or adulthood if they received no vaccinations and if they received all vaccinations and on-time. The difference in the subjective probability of side effects is "Exp. disease". "Exp. schooling" is the difference in the subjective expectation of the number of years of schooling the child will have received by age 30 if the child receives all vaccines on-time and if the child receives no vaccines. Mothers were also asked their subjective expectations of the index child's annual earnings at age 30. "Exp. log earnings" is the difference in the logarithm of the earnings expectations, winsorized at the 5th and 95th percentiles.

of mothers with very young infants in their catchment areas, and (b) mothers attending district health facilities on the days of Gallup field visits. Fifty-eight percent of respondents were recruited through health facilities.

4.2. Baseline data collection

The baseline data were collected through face-to-face interviews during the recruitment process. Panel A of Table 1 presents the baseline characteristics of the sample. The average respondent age is 28 years. In terms of education, 34% have completed primary school or less, while 37% have achieved middle or high school education. All respondents are married, and 17% of their spouses have completed primary school or less, while 36% have completed middle or high school education. Additionally, 40% of the respondents live in households earning more than Rs 30,000 (∼USD 105) per month ("high-income households"), while 63% live in rural areas.

On average, respondents have 2.6 children, including the index child for the study. At enrollment, the index child is 10 weeks old on average. Of all index children, 54% are boys.

Table F3 compares our sample to women in the 2017–2019 DHS who have a child aged six months or younger. Overall, our respondents are similar to the DHS population in terms of maternal age, fertility, and rural residence, although they are more educated. Children in our sample are also more likely to have received the BCG vaccine.

4.2.1. Vaccination

Respondents were asked a series of questions regarding their child's vaccination history, such as *"Has (NAME) ever received a BCG vaccination against tuberculosis, that is, an injection in the arm or shoulder that usually causes a scar?"* We used the wording from the Demographic and Health Surveys for this list (see Appendix B for details). As shown in Table F1, by the six-week mark, the child should have received a total of seven vaccines.

As shown in Panel B of Table 1, on average, the children had received 3.5 vaccines. The most commonly reported vaccines were BCG (89% of the children) and polio (82%), which are typically administered soon after birth.[4]

The "on-time vaccination" variable takes on the value of zero if, based on the mother's responses, the child has not received all the appropriate types of vaccines for their age, and equals one otherwise.[5] According to this definition, about a third of the sample is vaccinated on time at baseline.

4.2.2. Mental health

At baseline, we assess respondents' mental health using the PHQ9 battery, revealing generally poor mental health among the women surveyed. As shown in Panel C of Table 1, the average PHQ-9 score

[4] See Table F4 for summary statistics for the individual vaccines in our sample.

[5] This variable does not consider the number of vaccines of each type given, because this seems to be poorly measured, especially for vaccines given a long time ago. Children younger than six weeks are deemed to have been vaccinated on-time if the mother reports that the child has received the BCG, oral polio, and Hep-B vaccines. Children six weeks and older are considered vaccinated on-time by this definition if they have received the rota, pneumococcal, and pentavalent vaccines, in addition to the three vaccines required for younger children.

was 9.3, indicating a high prevalence of depressive symptoms. Notably, 41% of respondents were classified as depressed (PHQ-9 score of 10 or higher). Table F4 shows that 17% of mothers were classified as severely depressed (PHQ-9 score of 15 or higher). Additionally, 56% of respondents reported that they accomplished less than they wished in the past two weeks because of emotional problems.

4.2.3. Vaccination knowledge, attitudes and expectations

We also construct a knowledge score based on four questions asking about the number and timing of vaccinations (maximum score is 4, if all questions are correct—see Appendix B for the question wording). The average knowledge score is 2.6 out of 4. In addition, Table F4 shows that about a quarter of mothers report not being knowledgeable at all about vaccinations.

We also collect detailed vaccination-related expectations. These are important for establishing the channels through which the interventions may have an impact. We ask expected outcomes conditional on different vaccination status (*"What do you think will happen to (name) in the future depending on the vaccinations (name) receives as a child"*). We consider three different vaccinations statuses: receive all vaccinations, receive some, and receive none. We focus on three outcomes: the probability of contracting any of the diseases covered by the EPI (reported as a percent chance), total years of schooling, and household earnings at age 30. That is, the likelihood of each of these outcomes is elicited conditional on each of the three possible vaccination statuses. Table F5 shows that parents generally anticipate better outcomes if their child receives all or some vaccinations. For example, they expect their child to, on average, complete 14.6 years of schooling if they receive all vaccinations, 12.1 years if they receive some vaccinations, and 9.1 if they receive none. One exception is the perceived probability of contracting a disease, where the expectations are higher if the child receives all the vaccinations, potentially reflecting a misconception that vaccinations increase disease risk by exposing the child to pathogens. There is also heterogeneity in expectations, which can be seen in Appendix Figure F2 for expected education and expected household income across the three hypothetical scenarios. For our analysis of treatment effects, we focus on the difference in expectations between receiving all vaccinations and no vaccinations, as shown in Table 1. We see, for example, that the years of schooling are expected to increase by 5.4 years if the child receives all vaccines versus none.

Using all the expectations data, we construct an (Anderson, 2008) index based on four variables: (1) the difference in expected years of schooling at age 30, (2) the difference in indicators for having nonzero expected earnings at age 30, (3) the difference in log expected earnings at age 30 (winsorized at the 5th and 95th percentiles), and (4) the negative of the difference in the subjective probability of having an EPI disease, where all the differences compare the scenario in which the child has all their vaccinations and on time with the scenario in which the child has none of their vaccinations. The index is standardized to have mean zero and unit standard deviation for the control group. The endline index uses the same weights as the baseline index, but is also standardized so that the control group has mean zero and unit standard deviation.

We also collected attitudes toward vaccinations, as shown in Table F4. They are measured on a 0–10 scale, where zero means does not agree at all and 10 means fully agree. On average, at the baseline, mothers tend to agree that on-time vaccination is important (mean of 6). They also exhibit some concerns about side effects (mean of 5.3 for "vaccines have no or mild side effects").

4.2.4. Non-cognitive skills

We measure procrastination using a question derived from the Global Preference Survey and general self-efficacy using four items from a longer battery developed by Schwarzer and Jerusalem (1995), which evaluate individuals' beliefs in their ability to handle various challenging demands in life. Descriptive statistics for these variables can be found in Table F4. The average reported procrastination is 4.6 (on a 0–10 scale). In our analysis, we explore heterogeneity in the treatment effect based on these non-cognitive skills.

4.3. Midline and endline data collection

The midline data collection started in August 2022 and ended in April 2023. It was administered over the phone by Gallup. This is not our main focus but we present some midline treatment effects in Appendix D. The endline data collection started in April 2023 (roughly a year after the baseline) and was completed in September 2023. It was also administered over the phone by Gallup and was designed to be short to maximize response rates. We measure vaccinations again, vaccination knowledge, vaccination attitudes and expectations, and mental health.[6]

4.4. Engagement with the intervention

Participant engagement with the intervention was high across all calls. Counselors conducted brief well-being check-ins at the beginning and end of each session using a three-point scale (Good, Okay, Bad). These checks show large and consistent improvements in self-reported well-being: the share reporting "Good" rose from 76.7% to 97.2% over Call 1, 87.5% to 98.8% over Call 2, and 80.9% to 97.7% over Call 3.

Engagement with the Influencers component was also strong. In the PFA + Influencers group, only 35 out of 570 respondents declined to listen to at least one audio message during Call 2. After each recording, participants were asked to reflect on the message and report their level of agreement on a five-point Likert scale. Agreement was very high: across all messages, at least 522 of the 570 respondents (i.e., at least 91.6%) selected "Somewhat Agree" or "Completely Agree." Full distributions are reported in Appendix Table F6. Counselors also offered to share the audio messages via WhatsApp; 62.9% of the participants opted to receive them (most others did not have access to WhatsApp).

These indicators show that participants remained attentive during the calls and actively engaged with both the psychosocial support and informational components of the intervention.

4.5. Balance checks

Respondents were allocated to treatment at the time of the baseline interview using the random generator embedded in our data collection platform, SurveyCTO. Allocation is made at the individual-level, without clustering or stratification, with an intended probability of 1/3 for each group. Due to a coding mistake that was not detected at the baseline, the actual allocation likelihood of the control group was slightly higher. This is reflected in the larger sample size for the control group in Table 1. However, assignment was still random and, as shown in Table 1, the treatment and control groups are comparable on baseline observable characteristics. We employ the normalized difference approach as described in Imbens and Rubin (2015). As a general guideline, normalized differences below 0.25 in absolute terms suggest satisfactory balance within a standard regression framework (Imbens and Wooldridge, 2009). We observe normalized differences which are very close to zero, indicating that all the groups are similar in terms of observable characteristics.

4.6. Attrition

Attrition is a common issue in the context we study. The attrition rate is 47.5% in the Control group. It is higher in the two treatment groups: 50.9% in the PFA-only treatment (p-value of 0.200 for the test of equality with the Control group attrition rate) and 54.1% in the PFA + Influencers treatment (p-value = 0.012). The higher attrition in the treatment arms reflects the greater time commitment required by participation in the intervention relative to the control condition. This

[6] The average gap between the baseline survey and midline survey was 5 months, and between the baseline survey and endline survey was 12.4 months.

effect is most pronounced in the PFA + Influencers arm, which involved an additional call and therefore both increased respondent burden and created an additional opportunity to refuse continued participation. Consistent with this interpretation, refusal rates were 7% in the PFA arm and 11% in the PFA + Influencers arm.

The main reasons for attrition were phone disconnection or a busy line (45%), non-response (30%), refusal to participate (13%), the husband being away with the phone (7%), and the death of the mother or infant (5%).

Despite the differential attrition rate across the three groups, the baseline characteristics across them are reassuringly balanced in the endline sample, as shown in Table F7. We see that the normalized differences for demographic variables between the control and treatment groups at endline are close to zero. In our empirical analysis, we will conduct robustness checks to account for differential attrition.

5. Empirical analysis

5.1. Empirical strategy

We take advantage of the random assignment to treatments to estimate the causal effect of the interventions using the following regression:

$$Y_{m,1} = \beta_0 + \beta_1 T1_m + \beta_2 T2_m + \beta_3 X_m + \gamma Y_{m,0} + \varepsilon_m, \quad (1)$$

where the dependent variable $Y_{m,1}$ represents the child's immunization, expectations, knowledge, or mental health of mother m at endline survey, $T1_m$ is a binary indicator equal to 1 if the mother m is allocated to either treatment, and $T2_m$ is a binary indicator equal to 1 if the mother m is allocated to the PFA + Influencers treatment. That is, $T1_m$ equals 1 for both the PFA and PFA + Influencers treatments, while $T2_m$ captures the *additional* effect of the Influencers treatment. The vector X_m consists of pre-determined individual-specific characteristics (that we explain below) and $Y_{m,0}$ is the baseline outcome. Our preferred specification also includes months fixed-effects due to the seasonal pattern of mental health. We use robust standard errors. We aim to test the following hypotheses:

Hypothesis 1. The PFA treatment has no effect on outcome Y ($\beta_1 = 0$).

Hypothesis 2. The Influencers treatment has no additional effect on outcome Y ($\beta_2 = 0$).

We discuss our pre-registration in Appendix E.

5.2. Treatment effects on vaccinations

We start by estimating Eq. (1) for on-time vaccination status, the total number of vaccines received by the child, and the specific vaccines in Table 2. Panel A shows the results with a small set of controls (baseline outcomes, region, and an indicator for hospital-based recruitment). Our preferred specification in Panel B includes additional demographic controls: age of the child, number of children in the family, mother's education, ethnicity, an indicator for rural location, and household income; these are all thought to be important predictors of vaccination.[7] It also includes month fixed-effects. Results are consistent across the two panels.

In Panel B, column 2, the results show that children whose mothers were exposed to the PFA treatment receive significantly more vaccinations overall, with an estimated increase of 0.3 vaccines, representing a 7% increase over the control mean of 4.42. The positive effects of the PFA treatment are especially pronounced for vaccines that are often missed, such as pneumococcus, rotavirus, and the pentavalent vaccine. For instance, children in the PFA group exhibit a 6.2 percentage point increase in the likelihood of receiving the rotavirus (relative to a control mean of 49%) and an 8.9 percentage point increase in receiving the pentavalent vaccine (relative to a control mean of 53%). The larger treatment effects on vaccines that are typically scheduled at the 10-week mark or later are reassuring, since these are precisely the vaccines that were likely to have been impacted by our intervention.

In terms of on-time vaccination (column 1), the PFA treatment also shows a significant positive effect. Children in the PFA group were more likely to receive vaccines within the recommended schedule, with an estimated 7.4 percentage point increase; this is an economically large impact given that the control mean is 39%. This highlights the impact of the intervention not only on the total number of vaccines received but also on the timeliness of vaccinations.

In contrast, the Influencers treatment did not yield any additional impact on the timeliness of vaccinations, the total number of vaccines, or individual vaccine uptake, suggesting that the information shared through influencers did not reinforce the effects beyond what was achieved through the PFA intervention alone. If anything, the Influencers treatment appears to mute the treatment effects: the total number of vaccines increases by 0.20 for the bundled treatment arm, versus 0.30 for the PFA only treatment (difference not statistically significant at conventional levels; p-value = 0.52 without controls, and 0.35 with controls). So, even though the vast majority of our respondents agreed with the messages (Section 4.4), it seems that the messages did not reinforce — and may in some cases have attenuated — the effects of the PFA intervention. One possible explanation is that the messages induced some degree of reactance among a subset of individuals, although this is speculative.

5.3. Treatment effects on mental health, immunization knowledge, and expectations

When designing the intervention, the primary goal of the PFA intervention was to enhance childhood immunizations by assisting mothers in managing psychological constraints and fostering future-oriented thinking and planning. We start by evaluating whether our treatments had an impact on maternal mental health.

Table 3 shows that the interventions did not have a statistically significant impact on maternal mental health as measured by the PHQ-9 score, with a small and imprecisely estimated increase in the score for the PFA group and a null effect for the combined PFA + Influencers' treatment. It is therefore unlikely that the intervention operated through improvements in maternal mental health, although it may have helped alleviate short-term psychological strain not captured by the PHQ-9.

Column 2 of Table 3 shows a positive treatment effect of the PFA on the immunization knowledge score, with an increase of 2.7% relative to the control mean. This is despite the fact that the PFA did not provide any specific information on vaccinations. Ex ante, one may have expected the Influencers treatment to have an additional impact on the vaccination knowledge score, but we do not find evidence of that. As in the case of the impact on the number and timeliness of vaccines, if anything, the Influencers treatment mutes the impact on the knowledge score.

We next investigate the treatment effect on vaccination-related expectations. We specifically examine the perceived benefit of complete vaccinations versus no vaccination by calculating the difference in expected outcomes for each scenario. Table 3 shows the treatment effect on these perceived returns. In Column 3, we focus on the perceived reduction in the likelihood of contracting a childhood disease covered by the EPI due to full vaccination. The PFA exhibited a negative treatment effect, indicating that treated mothers perceived vaccination as more effective in preventing diseases compared to their untreated counterparts, with an effect size equivalent to 29.6% of the sample

[7] Since group assignment is random, this should not matter, in principle. Including the controls only helps with precision.

Table 2
Treatment effect on vaccinations.

	(1) On-time (Category)	(2) Total vaccines	(3) BCG	(4) Polio	(5) Hep B	(6) Pneumo	(7) Penta	(8) Rota
Panel A: Basic controls								
PFA	0.090**	0.322***	0.015	0.025	0.050*	0.056*	0.103***	0.072**
	(0.036)	(0.112)	(0.017)	(0.015)	(0.028)	(0.030)	(0.036)	(0.036)
Influencers	−0.019	−0.075	0.020	−0.015	−0.013	−0.018	−0.073*	0.024
	(0.038)	(0.117)	(0.015)	(0.015)	(0.029)	(0.031)	(0.038)	(0.038)
Observations	1057	1057	1057	1057	1057	1057	1057	1057
R-squared	0.071	0.069	0.014	0.008	0.040	0.023	0.056	0.060
Control mean	0.391	4.421	0.932	0.940	0.779	0.747	0.529	0.494
Panel B: Preferred controls								
PFA	0.074**	0.302***	0.021	0.027*	0.046	0.056*	0.089**	0.062*
	(0.035)	(0.112)	(0.017)	(0.016)	(0.029)	(0.030)	(0.036)	(0.036)
Influencers	−0.026	−0.108	0.018	−0.019	−0.014	−0.027	−0.079**	0.013
	(0.037)	(0.116)	(0.015)	(0.016)	(0.029)	(0.031)	(0.037)	(0.037)
Observations	1057	1057	1057	1057	1057	1057	1057	1057
R-squared	0.158	0.128	0.029	0.031	0.065	0.058	0.127	0.131
Control mean	0.391	4.421	0.932	0.940	0.779	0.747	0.529	0.494

Note: The dependent variable in Column 1, "On-Time (Category)", is equal to one if the mother reports the child has received at least one of each of the required types of vaccines appropriate for the child's age, and zero otherwise. The dependent variable in Column 2, "Total Vaccines", is the sum of the 6 binary variables in Columns 3–8. All regressions control for the baseline outcome, Swabi (location), and whether recruitment was at a hospital. Panel B additionally controls for the number of children, age of youngest child, ethnicity indicators, rural/urban status, whether the mother has primary schooling, whether the household has high income, indicators for the mother's reported health, and month FEs. Robust (HC3) standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$ *** $p < 0.01$.

Table 3
Treatment effect on mental health, knowledge regarding immunizations, and expectations for child.

	(All vac. - No vac.)						
	(1) PHQ-9 score	(2) Knowledge score	(3) Exp. disease	(4) Exp. schooling	(5) Exp. NZ income	(6) Exp. log earnings	(7) Exp. index
PFA	0.474	0.073**	−8.582*	0.329	−0.008	0.100**	0.167**
	(0.367)	(0.037)	(4.821)	(0.375)	(0.021)	(0.049)	(0.072)
Influencers	−0.315	−0.026	−0.033	−0.292	−0.017	−0.071	−0.108
	(0.391)	(0.038)	(4.960)	(0.387)	(0.022)	(0.054)	(0.073)
Observations	1057	1057	1057	1032	922	616	1057
R-squared	0.055	0.053	0.143	0.058	0.052	0.047	0.135
Depvar control mean	7.995	2.667	−29.023	6.178	0.079	0.528	−0.000

Note: The PHQ9 score is an indicator of maternal mental health. A higher PHQ9 score implies worse maternal mental health. The knowledge score is based on four questions asking about the number and timing of vaccinations (maximum score is 4 if all questions are correct). Column 3 is the difference in the mother's subjective probability that the index child would get any serious side effects in childhood or adulthood if they received all vaccinations and on-time and if they received no vaccinations. Column 4 is the difference in the mother's subjective expectation of the number of years of schooling her child will have completed at age 30. Column 5 is the difference in binary variables for whether the mother reports a non-zero and non-missing subjective expectation for her child's monthly income at age 30 if the child is fully vaccinated and if the child received no vaccinations. Column 6 is the difference in the logarithm of these monthly income expectations, conditional on reporting non-zero and non-missing expectations, with the log difference winsorized at the 5th and 95th percentiles. Column 7 is the Anderson (2008) index for the expectations variables in Columns 3–6, using the baseline data for weighting the variables. The index is standardized to be mean zero and unit variance for the control group. All regressions include controls for Swabi, whether recruitment was at a hospital, the baseline value of the dependent variable, number of children, age of youngest child, ethnicity indicators, rural/urban status, whether the mother has primary schooling, whether the household has high income, indicators for the mother's reported health, and month FEs. Robust standard errors (HC3) in parentheses. * $p < 0.10$, ** $p < 0.05$ *** $p < 0.01$.

mean. The Influencers treatment had no additional impact. Column 4 shows no treatment effect on the expectation that vaccinating children may improve their schooling. In terms of earnings, we see no impact on the likelihood of reporting a non-zero expected income (column 5). However, conditional on reporting positive earnings, there is a positive effect on expected log earnings (column 6), representing an increase of 19% relative to the control mean. To address potential concerns about multiple hypothesis testing, we also present the treatment effect on the expectation index (described in Section 4.2.3). The results indicate that the PFA treatment increases positive expectations about vaccinations by 17% of a standard deviation; as was the case with the results in Table 2, the Influencers treatment generally attenuates the impact on expectations.

In summary, these results suggest that the PFA did not have a noticeable impact on maternal mental health, but did improve knowledge and expectations about the benefits of vaccination. Since the PFA intervention did not directly provide vaccination-related information, the effects are likely due to improved engagement with the vaccination process and the healthcare system more broadly. The Influencers treatment, on the other hand, did not produce any additional significant effect on vaccination knowledge. It is possible that, in a context characterized by anti-vaccine propaganda (Martinez-Bravo and Stegmann, 2022), the messages from the Influencers may have inadvertently undermined the effectiveness of the PFA intervention.

5.4. Treatment effects on attitudes and behavioral measures

Columns (1) to (4) of Table 4 examine the effects of the interventions on mothers' attitudes towards vaccinations. The table presents regression results where the dependent variable is the mother's level of agreement (on a scale of 0 to 10) with different statements about vaccinations. Column (2) shows that the PFA intervention led to a statistically significant increase in mothers' agreement with the statement that "Some diseases that are preventable by vaccinations can be very serious for a child's health". This is consistent with the impacts shown in Table 3, since it suggests that the PFA intervention increased

Table 4
Treatment effect on attitudes and willingness to pay for reminders.

	Attitudes					
	(1) On-time vax important	(2) Prevent serious	(3) Mild side effects	(4) Attitude index	(5) Vax hassle	(6) WTP reminders
PFA	0.040	0.545*	−0.249	0.042	0.532*	−18.971
	(0.109)	(0.303)	(0.281)	(0.072)	(0.310)	(28.708)
Influencers	0.082	0.088	0.167	0.066	−0.646**	39.083
	(0.096)	(0.313)	(0.294)	(0.074)	(0.328)	(29.726)
Observations	1057	1057	1057	1057	1057	1057
R-squared	0.030	0.063	0.067	0.064	0.117	0.076
Depvar control mean	9.491	6.053	6.291	0.000	3.694	214.361

Note: The dependent variables in Columns 1–3 are integers, ranging from 0 to 10, indicating respondents' agreement with statements about vaccines. Column 1 is "It is important for a child to be vaccinated on time". Column 2 is "Some diseases that are preventable by vaccinations can be very serious for a child's health". Column 3 is "Vaccinations mostly have no or mild side effects such as fever, rash, irritability". Column (4) is the Anderson (2008) index for the variables in Columns 1–3, using the weights from the baseline index. The index is standardized to have mean zero and unit variance for the control group. Column 5 is "It is a hassle to organize for my child to be vaccinated". The respondents were asked whether they would prefer to receive a phone reminder (SMS) prior to the date of child's vaccination or airtime money. Airtime money of Rs 10, Rs 100, Rs 300 and Rs 800 in lieu of the reminder was randomly offered to the respondents. Column 6 captures the treatment effect on respondents' willingness to pay for phone reminders. If a respondent is unwilling to forego Rs 10 for a reminder, her WTP is set to 0. If she is willing to pay for reminders, her WTP is set to the largest value for which she prefers reminders above airtime. Respondents who prefer a reminder above Rs 800 of airtime are assumed to have a WTP of Rs 1000. All regressions include controls for Swabi, whether recruitment was at a hospital, the baseline value of the dependent variable, number of children, age of youngest child, ethnicity indicators, rural/urban status, whether the mother has primary schooling, whether the household has high income, indicators for the mother's reported health, and month FEs. Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$ *** $p < 0.01$.

mothers' perceptions of the severity of vaccine-preventable diseases. However, we see no significant treatment effect on mothers' views regarding the importance of on-time vaccination (column 1), the mildness of vaccination side effects (column 3), or the overall attitude index (column 4). We also see that the PFA intervention increased mothers' agreement with the statement that "It is a hassle to organize for my child to be vaccinated", highlighting the logistical challenges faced by those who had their children vaccinated. This effect is not there for the PFA + Influencers treatment.

Column (6) reports the treatment effect on mothers' willingness to pay for phone reminders, showing that neither intervention had a statistically significant impact on this outcome.[8] It is worth noting that participants had already received reminders, allowing them to assess the effectiveness of phone reminders firsthand. This null result suggests that forgetting the vaccination schedule may not be a primary concern for these mothers.

5.5. Heterogeneity analysis

We next investigate heterogeneity in our treatment effects. We investigate aspects of heterogeneity outlined in our pre-registration, which is discussed in Appendix E. For reasons of power, we present heterogeneity in the pooled treatment effect, where individuals assigned to either the PFA or the PFA + Influencers arm are coded as treated. Results are presented in Table 5. The variable used for the interaction with the treatment indicator (i.e., the moderator) is shown under the column number. We estimate the following specification:

$$Y_{m,1} = \alpha_0 + \alpha_1 \text{Treat}_m + \delta \left(\text{Treat}_m \times M_m\right) + \alpha_2 X_m + \gamma Y_{m,0} + \varepsilon_m, \quad (2)$$

where $\text{Treat}_m = 1$ if individual m was assigned to either treatment arm (PFA or PFA + Influencers), and M_m denotes the mediator of interest. The vector X_m contains basic controls.[9] δ is the parameter of interest.

The first column in Table 5 shows that mothers' mental health at baseline, as measured by the PHQ-9 score, does not have a significant interaction with the treatment. However, this masks a non-linear relationship between the treatment and mental health. Appendix Table F8 interacts the pooled treatment with terciles of maternal mental health; here, columns (1) and (3) show that the treatment effect (on both the number of vaccines and on-time vaccination) is strongest for those in the second tercile, providing suggestive evidence that mothers with intermediate levels of mental health are most receptive to the treatment; it is, however, worth noting that we cannot reject the hypothesis that the estimates on the three terciles are the same (as shown by the p-value at the bottom of the table).

Column 2 of Table 5 shows that the treatment effect on vaccination is concentrated among low-income families, who may face more binding constraints on both time and material resources. In contrast, no significant differences in treatment effects are observed by maternal education levels (column 3).

Procrastination, as a measure of a mother's tendency to delay tasks, shows no significant interaction effect with the treatment on total vaccinations or on-time vaccinations (column 4). However, self-efficacy, reflecting confidence in one's ability to manage challenges, does have a large and significant positive interaction with the treatment for both total vaccination and on-time vaccination (column 5). This result underscores the potential role of self-efficacy in health-related decision-making, where more confident mothers are more likely to follow through with (timely) vaccinations when provided with additional support. This can also be seen in Table F8 (columns 2 and 4), where the treatment effect is interacted with terciles of self-efficacy, providing suggestive evidence that the on-time vaccination impact is driven by mothers in the highest self-efficacy tercile; again, however, we cannot reject the null that the estimates on the three terciles are equal.

Column 6 of Table 5 shows that the treatment effect is larger for those with a lower baseline expectations index; that is, our intervention has larger impacts for mothers whose baseline expectations regarding vaccines were relatively less positive. Columns 7 and 8 indicate that the interventions' effectiveness is similar regardless of the child's gender or

[8] As shown in appendix B, respondents were presented with an incentivized price list where they had a choice of receiving mobile phone airtime of a certain value or a phone reminder. The values were Rs. 10, Rs. 100, Rs. 300, or Rs. 800; for each of these values, the respondent had to make a choice.

[9] Treatment is randomized, so unbiased estimation does not require controls. Here, we include a small set of design/recruitment controls (hospital recruitment and Swabi) and the baseline outcome to improve precision at low parameter cost. Our main results on vaccinations, mental health, and beliefs are robust to using either set of controls. For heterogeneity, effective sample sizes are small; adding a high-dimensional set of fixed effects and other controls can over-parameterize the model and inflate standard errors in finite samples. We therefore use the parsimonious specification for these power-constrained analyses. It is, however, worth noting that the main heterogeneity results that we present in Table 5 below are robust to the choice of controls.

Table 5
Treatment effect heterogeneity on total and on-time vaccinations.

	(1) PHQ-9	(2) High income	(3) Sec educ plus	(4) Procras -tinate	(5) Self efficacy	(6) High expect.	(7) Girl child	(8) First -born	(9) On-time vax
Panel A: Total vaccines									
Treated	0.217	0.374***	0.251*	0.346*	−0.419	0.509***	0.303**	0.237**	0.202*
	(0.171)	(0.120)	(0.130)	(0.202)	(0.361)	(0.149)	(0.133)	(0.111)	(0.122)
Treated × Moderator	0.008	−0.268	0.075	−0.014	0.283**	−0.405**	−0.040	0.196	0.246
	(0.017)	(0.208)	(0.195)	(0.038)	(0.133)	(0.197)	(0.197)	(0.235)	(0.205)
Observations	1057	1057	1057	1057	977	1057	1057	1057	1057
R-squared	0.069	0.070	0.086	0.069	0.078	0.074	0.068	0.070	0.072
Control mean	4.421	4.421	4.421	4.421	4.421	4.421	4.421	4.421	4.421
Panel B: On-time vaccination (category)									
Treated	0.087	0.115***	0.079**	0.116*	−0.247**	0.157***	0.072*	0.086**	0.063*
	(0.055)	(0.037)	(0.040)	(0.063)	(0.118)	(0.045)	(0.041)	(0.035)	(0.038)
Treated × Moderator	−0.001	−0.101	0.002	−0.008	0.126***	−0.139**	0.017	−0.024	0.052
	(0.005)	(0.065)	(0.062)	(0.012)	(0.044)	(0.061)	(0.061)	(0.071)	(0.064)
Observations	1057	1057	1057	1057	977	1057	1057	1057	1057
R-squared	0.072	0.077	0.085	0.073	0.079	0.076	0.071	0.071	0.071
Control mean	0.391	0.391	0.391	0.391	0.391	0.391	0.391	0.391	0.391

Notes: Each column reports a specification interacting treatment assignment with a different baseline moderator, which is indicated by the column title. All moderators are measured pre-treatment. PHQ-9 is the sum of nine 0–3 items (range 0–27). High Income equals 1 if baseline household income is above the sample median. Sec Educ Plus equals 1 if the mother has secondary education or higher. Procrastinate equals 1 if the mother's 10-point Likert response to "I tend to postpone task…" is above the sample median. Self-efficacy is constructed by taking the unweighted average of four 4-point Likert items (range 1-4); it is missing if any component item is missing or "don't know". High Expect equals 1 if the baseline expectations index (Anderson index over perceived disease reduction, schooling gains, and income/earnings expectations) is above the sample median; the log earnings return is winsorized at the 5th and 95th percentiles. Other binary moderators are defined as indicated (e.g., Girl Child, Firstborn, On-time Vax). All regressions include the moderator main effect, the baseline value of the outcome variable, an indicator for hospital recruitment, and for being in the Swabi district. Robust (HC3) standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$ *** $p < 0.01$.

birth order. Finally, column 9 shows that the effects do not differ by whether the child had been vaccinated on time at baseline.

Overall, the heterogeneity analysis shows quite sensible patterns. The impacts are larger for households with lower income and those with less optimistic baseline expectations about the benefits of vaccines. In addition, the treatment is particularly useful for mothers with higher levels of self-efficacy, who may be better able to follow through on their intention — especially with regards to on-time vaccination — when treated. Finally, we find that mothers with intermediate levels of mental health benefit the most; mothers who were already in good mental health or were more severely depressed benefited less from the intervention. The tercile-based patterns for self-efficacy and mental health should be interpreted as suggestive, since we cannot reject equality of treatment effects across terciles.

5.6. Robustness checks

5.6.1. Attrition

We noted earlier that about half of the sample was not interviewed at endline. We investigate whether our results are robust to attrition. We first compute attrition bounds following Lee (2009), which assess treatment effects under worst-case selection consistent with a monotone attrition assumption. This approach ranks outcomes within each treatment arm and trims observations from the group with lower attrition (from either the upper or lower tail) in order to equalize effective sample sizes across groups. Calculating mean differences between the trimmed samples yields lower and upper bounds on the treatment effect. Table C1 reports the Lee bounds for the treatment effects on vaccinations, mental health, knowledge, and expectations.

For the PFA intervention (column 1), the bounds for total vaccinations remain strictly positive (ranging from 0.015 to 0.499), indicating that the main PFA effect is robust to worst-case assumptions about selective attrition. In contrast, for the PFA + Influencers arm relative to the PFA arm (column 2), the attrition-adjusted bounds for total vaccinations are strictly negative (ranging from −0.37 to −0.05), and similarly negative bounds appear for several individual vaccines (polio, hepatitis B, penta) as well as for the vaccination knowledge index. This allows us to rule out large positive effects of the combined intervention relative to the PFA group. At the same time, the bounds do not rule out the possibility of negative effects for the PFA + Influencers treatment.

We also take a more parametric approach in Table C2 by estimating the treatment effects using inverse probability weighting with regression adjustment (IPWRA), as in Cattaneo (2010). Treatment propensities for respondents observed at endline are estimated using a multinomial logit model, and the inverse of these propensities is used to weight outcome regressions that additionally control for baseline outcomes and covariates. This estimator is doubly robust and yields consistent average treatment effects if either the propensity score model or the outcome regression is correctly specified.

The IPWRA estimates reinforce the main conclusions. For the PFA arm (column 1), the estimated effects relative to the control group on total vaccinations, several individual vaccines, and vaccination knowledge remain positive, precisely estimated, and similar in magnitude to the main specification, indicating that the effectiveness of PFA is robust to differential attrition under parametric assumptions. In contrast, the IPWRA estimates for the PFA + Influencers arm show no evidence of positive effects relative to the PFA group.

Overall, both nonparametric bounds and parametric attrition adjustments support the conclusion that PFA robustly increases vaccination uptake, whereas the combined PFA + Influencers intervention does not improve outcomes relative to the PFA group. While differential attrition in the PFA + Influencers arm warrants caution, the results consistently rule out large positive effects of the combined intervention in this context, reinforcing the conclusion that adding influencer messaging does not enhance, and may attenuate, the effectiveness of PFA.

5.6.2. Desirability bias

It is important to note that our vaccination measures are self-reported, raising the possibility of social desirability bias.

Several design features reduce the scope for differential reporting across treatment arms. First, enumerators conducting the endline survey were distinct from the counselors who delivered the intervention, reducing incentives for respondents to please their counselor. Second, the PFA + Influencers arm, despite involving an additional call and explicit pro-vaccination messages, does not generate larger treatment effects. If social desirability bias were driving the results, one would

expect the strongest effects in this arm, which is not what we observe. Third, we attempted to validate self-reported vaccination outcomes by requesting respondents to send a photo of their child's immunization card. Although compliance was limited (409 submissions), the partial correlation (using the full set of controls) between self-reported vaccinations and the card-based counts is 0.23, indicating substantial alignment between the two measures. Importantly, the likelihood of submitting a card photo does not differ by treatment status.

Finally, recent work that directly manipulates experimenter demand in a structured way suggests that such effects are typically modest. de Quidt et al. (2018) and Danz et al. (2024) study strong applied demand manipulations and conclude that demand effects are generally too small to reverse qualitative inferences about treatment effects. Taken together with our design features that mitigate demand, these findings make it unlikely that experimenter demand alone could generate the magnitude or direction of effects we observe.

6. Discussion

We demonstrate the effectiveness of an intervention providing light psychological support, as well as visualization and planning techniques, in increasing childhood immunization rates in rural Pakistan. Our results show an additional 0.3 vaccines administered per child relative to a control mean of 4.42, along with a 7.4 percentage point (ppt) increase in on-time vaccinations (relative to a control mean of 39%). These effect sizes align closely with recent demand-side interventions. For instance, Karing (2024) reports a similar impact in Sierra Leone, where social signaling resulted in an additional 0.35 vaccines per child from the same control mean of 4.42 and a 9.4 ppt increase in timely vaccination by age one. Similarly, Chandir et al. (2022) finds that mobile-based conditional cash transfers in Pakistan increased full immunization coverage at 12 months by 6.8 ppt from a control mean of 56%. In Kenya, Gibson et al. (2017) provided reminders and 2 USD per on-time vaccination, achieving an 8 ppt increase in full immunization by 12 months from a control mean of 82%.[10]

In terms of cost, our intervention is relatively more expensive than several other demand-side approaches. Karing (2024) reviews the cost-effectiveness of multiple interventions, reporting costs close to 25 USD per fully immunized child at 12 months (e.g., studies by Banerjee et al. 2010, Karing 2024, Banerjee et al. 2024), with some higher, such as 90 USD in Gibson et al. (2017). Our PFA intervention costs 24 USD per child when considering only counselors' salaries and 57 USD when accounting for training, supervision, psychologist salaries, and operational costs like internet and phone services. It is also worth noting that our intervention has impacts on other margins, including attitudes and knowledge about health behaviors, which are likely to have spillover effects on other human capital outcomes that we do not capture in our study.

On the methodological front, our results show that appropriately designed psychological, visualization and planning interventions — even when light-touch — can generate meaningful impacts on childhood immunizations. Leveraging internal motivators may be particularly effective in contexts characterized by vaccine hesitancy, anti-vaccine propaganda, and low trust in authorities.

[10] In an earlier study with a lower baseline vaccination rate in rural India, Banerjee et al. (2010) find that non-monetary incentives increased full immunization rates among children aged 1–3 years by 21 ppt, from a baseline of 18%. Focusing on measles, Banerjee et al. (2024) test a large number of vaccination nudges in Haryana, India, finding that the most effective nudge increased the number of measles vaccinations per village by 3.26 per month, which is a 45% increase compared to the control mean of 7.32.

CRediT authorship contribution statement

Adeline Delavande: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Areeba Shahab:** Visualization, Validation, Supervision, Resources, Project administration, Methodology. **Javed Younas:** Writing – review & editing, Writing – original draft, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Basit Zafar:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Formal analysis, Conceptualization.

Appendix A. Supplementary material

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.jdeveco.2026.103808.

Data availability

Data will be made available on request.

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