How PROMPTS Uses Data Science and Machine Learning to Identify & Refer At-Risk Mothers for Care at the Right Time & Place
Bungoma County, Kenya — Josephine was in the later stages of pregnancy when she received a message from PROMPTS that would save her life. ‘It said pain in the upper abdomen is a danger sign.’ she explains. ‘One day, I felt this pain. I thought it’d pass, but it didn’t.’ Realizing this correlated with the warning, she went to a nearby clinic where her blood pressure was tested and found high, and she was referred and admitted into urgent care. ‘For three days, my baby didn’t move’, explains Josephine. The hospital took action, performing an emergency cesarean section that would save her, and her baby’s life. ‘I’m so grateful for these messages.’ she says. ‘I could recognize my pain wasn’t normal and got help. I don’t know what might have happened otherwise.’

One significant driver of maternal and newborn deaths in Kenya is that many women are not informed or empowered to recognize signs of potential complications such as vaginal bleeding during pregnancy or a severe headache and blurred vision. For other women, it’s the lack of ability or opportunity to act on these danger signs in the face of conflicting priorities, including child care and domestic responsibilities, or concerns about income lost during the time seeking care. These converging factors around recognizing and acting on danger signs, contribute to 33% of maternal deaths in Kenya.

PROMPTS: IDENTIFYING AND REFERRING AT- RISK MOTHERS TOWARDS APPROPRIATE CARE PATHWAYS.

To address this challenge, Jacaranda Health has developed PROMPTS - a low-cost, scalable digital health platform that empowers new and expectant mothers to seek care at the right place and time. It improves care-seeking behaviour by sending mothers gestation-stage specific “nudge” text messages, alongside a two-way helpdesk service which responds to thousands of messages from mums each day in English or Swahili. The PROMPTS platform uses Natural Language Processing (NLP), a machine learning approach, to triage and prioritize messages from mums for clinical danger signs. This, in turn, allows Jacaranda’s clinical helpdesk agents (qualified nurses and medics) to rapidly respond to and refer urgent cases for care - all within an hour.

Alongside machine learning, Jacaranda also uses behavioral science to ensure mothers with potential complications are able to self-identify these issues and communicate the danger. PROMPTS sends mothers on the platform a ‘danger signs survey’ aligned with key milestones in their pregnancy (trimesters 1,2, and 3) and critical days following delivery (days 2,3,4, and 5). Survey questions are designed to catch danger signs early at the level of both mother (are you feeling dizzy or having difficulty breathing?) and baby (does your baby have a reduced body temperature?), advising referral if the signs are recognized.

[1] Confidential Enquiry into Maternal Deaths (CEMD), 2017
A survey sent in the first trimester might read: Watch for danger signs in pregnancy. Do you experience vaginal bleeding, severe nausea, vomiting, fever, or severe abdominal pain? If you see any of these danger signs, respond with an explanation of what you are seeing and go to the nearest hospital immediately.

A survey sent a couple of days after delivery might read: Has your baby’s cord fallen? Does it have any signs of infections such as redness, swelling, or pus discharge? Are your baby’s eyes yellow, or is he or she experiencing fever, rapid breathing, or making little to no movements? If you see any of these danger signs, respond with an explanation of what you are seeing and go to the nearest hospital immediately.

This survey also screens for lower priority cases that can be managed at home. An example screening question could read: Has your baby had any vaccinations within the past week? Sometimes vaccinations cause high fever.

By combining AI-powered triaging and prioritization of incoming messages from mums, with user-submitted survey data, Jacaranda has seen a shift in women’s understanding of potential complications (71% of prenatal mothers using PROMPTS can now name 3+ pregnancy danger signs).

Most importantly, we’ve also an increase in action taken after referral (85% of mums flagged with a danger sign now go to hospital).

A DATA-DRIVEN APPROACH TO UNDERSTANDING WHY, WHEN, AND WHERE MUMS NEED EMERGENCY CARE.

PROMPTS has already reached over a million women across Kenya, with evidenced success in applying AI-based systems to launch them on appropriate care pathways through a network of over 1,000 government partner facilities. As the platform scales, it is critical to maintain a tailored approach to identifying and acting on danger signs across an increasingly diverse user base of mothers. To do this, we need to deepen our understanding of where at-risk mothers are, and strategies for better identifying and engaging them to improve risk stratification.

[2] Adapted from McConnell et al., 2016, BMC Childbirth and described in Jones et al., 2020, PLOS One
[3] Insights from a PROMPTS quarterly survey amongst its users, conducted in September 2021
Identifying & Refering At-Risk Mothers at the Right Time & Place

WE IDENTIFIED SOME KEY INSIGHTS - THROUGH PROMPTS DATA - TO HELP US INCREASE THE EFFICIENCY AND SPEED BY WHICH WE IDENTIFY MOTHERS WHO NEED URGENT CARE.

A few danger signs account for 90% of hospital referrals. PROMPTS classifies the messages it receives from mothers by ‘intents’ - ranging from nutrition to newborn care - helping our machine learning read and determine whether the sender needs additional support. Exploring which intents are most likely to need follow-up increases our understanding and therefore responsiveness to certain types of incoming messages, which is especially useful as Jacaranda moves towards scaling and growing its helpdesk.

Our analysis shows just ten types of risks reported to PROMPTS account for ~90% of referrals, with ‘headache’ and ‘other’ constituting the bulk of referred cases (42%). This data offers a springboard to improve our triaging process of mothers, including training our machine learning model (NLP) to disaggregate intents like ‘other’, building capacity among our helpdesk agents to resolve frequently occurring risks, or more proactively engaging mothers with educational ‘headache’ messaging to quickly identify pre-eclampsia (a condition affecting pregnant/postpartum women often signposted by severe headaches).

Figure 1: A breakdown of the most frequently reported danger signs from June to December 2021.
Knowing where there are higher rates of referrals to care informs the support we provide county health systems. When looking at the distribution of hospital referrals by county, we find that they are slightly higher in Nairobi (21%) and Nakuru (24%), Kenya’s capital city and fourth largest city respectively. There are likely to be multiple factors contributing to geographic disparities in hospital referrals; women living in urban areas may be more comfortable messaging the platform based on higher digital literacy rates, or may be more inclined to seek remote support due to overcrowded facilities with long wait times.

Further qualitative studies will help identify the factors driving county differences, the data of which can be used to identify possible service delivery challenges including staff shortages, poor care quality, or irregular facility opening times discouraging women from seeking timely care.

Conversational history can help us determine risk. Currently, PROMPTS takes a single SMS message sent by a mum and assesses whether a mother needs urgent care. However, what a mother has told us before may point to an increased risk of experiencing a danger sign later on.

Jacaranda is exploring machine learning tools, such as random forest analyses to determine correlations between user history and a hospital referral. Preliminary analyses indicate that individual conversational history is robust enough to build a predictive model, as shown by the chart on the right. The model has a 75% true positive rate of identifying an at-risk mum, but we need to optimize the model to reduce the number of false positives detected.

We are now working to see how these algorithms can be integrated with the helpdesk interface for enhanced triaging based on historical messaging patterns, helping us connect women to appropriate care pathways faster.
Identifying & Refering At-Risk Mothers at the Right Time & Place

Tracking the referral process is critical to ensuring a mother gets care. Incentivizing mothers to self-report on their health and wellbeing helps build a nuanced understanding of what danger signs result in adverse outcomes, and when and where these are likely to happen. But to close the loop, we need to know what happens after our helpdesk has referred an at-risk mother to care; whether a successful outcome (mothers reporting they went to hospital) or an unsuccessful outcome (mothers who didn’t go to hospital, or else did not respond to the referral call or message).

Our helpdesk escalation protocols ensure that we follow up with every mother who has reported a danger sign, and who has had a subsequent follow-up call. During a recent analysis of helpdesk ‘escalations’, we found that many women had already self-resolved their issues (eg. headache, bleeding) in an appropriate way (seeking care, taking recommended medication) before receiving a call from our helpdesk agents.

**Figure 3.** Percentage volume of escalations to the helpdesk between June and December 2021, disaggregating mothers who sought actual care versus those who did not.

This is a strong reminder of the effectiveness of empowering women with information - via routine messages explaining what danger signs look like and how to act on them - in driving positive health outcomes. Jacaranda is also exploring ways to build a stronger rapport with mothers from first enrollment to the platform (eg. an introductory message) so that they become familiar, and therefore receptive to a referral call from one of our helpdesk agents.
We developed a sophisticated Helpdesk Client Management Tool to support our rapidly scaling helpdesk service. As the volume of PROMPTS queries has increased, we recognized the limitations of our existing commercially available helpdesk tool: the system was not customized to handle multiple agent workflows, integration with machine learning, escalations and phone support. This resulted in unacceptable operational delays in responses to mothers’ questions. At scale, this process was unsustainable.

We customized and developed a PROMPTS-specific helpdesk tool, built on the cloud computing software Salesforce. The tool has improved agent workflow, and therefore the rate at which the helpdesk can respond and seamlessly refer mothers to care at the right time and place.

Figure 4. The interface of our helpdesk client management tool.

Agents are assigned tickets according to their level of expertise and can holistically map each user’s journey and message history in one place, helping make informed decisions that lead to better care. When referral is needed, they dial directly from the interface using a click-to-call functionality. The PROMPTS helpdesk tool has also transformed the way we collect and manage data from mothers, meaning our county partners have a more accurate analysis of mothers’ experiences in facilities, and can better allocate resources. With better insight into helpdesk’s operations, oversight of each user journey, and increased opportunities for automation, we’re now able to serve mothers faster and more accurately – and achieve this at national scale and beyond.
WHAT’S NEXT? AS PROMPTS EXPANDS, WE WILL STRENGTHEN OUR CAPACITY TO MORE QUICKLY AND INTUITIVELY IDENTIFY AT-RISK MOTHERS ON THE PLATFORM.

It’s clear from these insights that further qualitative studies around message source, content, and location are needed to improve risk stratification for the women relying on PROMPTS to navigate their pregnancies. This might include more proactive risk screening at the onset of pregnancy, including gathering data on obstetric history, risk factors such as prior preterm birth, or social determinants like alcohol use, to identify high risk mothers earlier and launch them on the best care pathway.

Combining ‘risk profiles’, routine user-reported data, and improved technology infrastructure, we’re working with national and private sector partners to make PROMPTS a national digital health solution supporting advanced engagement, education, triage and risk assessment for expectant and new mothers across Kenya.

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