

Design and Evaluation of an AI-Assisted E-Governance ICT Solution to Empower Non-Literate Rural Healthcare Consumers

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ABSTRACT

Rural healthcare consumers in low-literacy regions face persistent barriers to accessing e-governance health services because most digital health portals assume reading proficiency, stable internet access, and familiarity with graphical interfaces. This study designs and evaluates an AI-assisted e-governance ICT solution that replaces text-dependent interaction with a voice-first, multilingual conversational interface built on Automatic Speech Recognition (ASR), Natural Language Understanding (NLU), and Text-to-Speech (TTS) components layered over an existing government health database. A mixed-methods pilot was conducted across three rural districts (N = 240 households) over an eight-week deployment window, comparing the proposed system against a conventional text-based portal on task completion time, System Usability Scale (SUS) scores, ASR/intent accuracy, and adoption rate. Results indicate that the AI-assisted voice interface reduced mean task completion time by approximately 61%, achieved a mean SUS score of 81.1 (interpreted as 'good' usability) across literacy groups, and reached a cumulative adoption rate of 76% by week eight, compared with markedly slower uptake historically reported for text-based government portals. The findings suggest that voice-first, AI-mediated e-governance interfaces can materially close the digital health access gap for non-literate rural populations, while highlighting connectivity, dialectal variation, and trust-building as remaining design challenges. The paper concludes with policy implications for national digital health inclusion strategies and directions for future work on offline-capable, federated AI models.

Keywords: *E-Governance; Artificial Intelligence; Digital Health Literacy; Voice User Interface; Rural Healthcare; Non-Literate Users; ICT4D*

Introduction

In the developing world, governments have poured money into e-governance platforms for the provision of public health services to the under-served. In line with the digital-first vision in national and international digital health policy plans (World Bank, 2021; World Health Organization, 2022), Pakistan's digital health strategy has been focused on web and mobile portals for the appointment bookings, tracking of vaccinations, notification of medicine availability, and symptom reporting. The effectiveness of these platforms is limited by the structural mismatch: e-governance interfaces are almost entirely text and literacy dependent while significant portion of the rural population, especially women and elders, are unable to reliably read or navigate through the menu driven digital forms (Pakistan Bureau of Statistics, 2023). This mismatch leaves a secondary digital divide where infrastructure is present, but not fully usable for the consumers who most need it and which, in turn, contributes to overall disparities in human development outcomes across the region (UNDP, 2023). Artificial Intelligence (AI) seems a likely solution to fill this void. However, with the advancement of Automatic Speech Recognition (ASR) and intent classification for low-resource languages, and also Text-to-Speech (TTS) synthesis for South Asian languages, it is now possible to develop conversational voice-first interfaces without reading or writing. These AI layers can be used on top of existing government health databases, and translate from local language to spoken input and back from structured output to natural, spoken language, without replacing e-governance back-ends. Such a system is designed, implemented and field tested and reported here. The specific objectives of the study are: (i) Designing a voice first, AI mediated, rural e-health governance architecture; (ii) Implementing multilingual (ASR/NLU/TTS) pipelines for four regional languages; (iii) Making empirical comparisons of the proposed system with a traditional text-based e-health portal based on efficiency and usability metrics; and (iv) Computing a composite Digital Health Empowerment Index (DHEI) for quantifying the impact of the proposed system in improving access to publicly provided health services for non-literate consumers.

Literature Review

Past studies on ICT4D (Information and Communication Technologies for Development) have reported that literacy is often the limiting factor for the adoption of e-governance in rural areas (Heeks, 2022). Research efforts in India and East Africa have demonstrated that voice channels can provide much higher engagement rates than SMS or App based channels with the majority of legacy IVR systems in a rigid, menu based tree structure and not a natural conversation with the user (Patel et al., 2021; Gupta & Singh, 2020).

In parallel, there have been advances in low-resource NLP that have reduced the gap in ASR accuracy performance between low-resource languages like Urdu, Punjabi, Sindhi, and Pashto and the high-resource languages like English, although word error rates (WER) in the noisy rural field are still high (Ali & Rahman, 2023; Devi & Kumar, 2022). Moreover, research on e-governance adoption using the Technology

Acceptance Model (TAM) and the Unified Theory of Acceptance and Use of Technology (UTAUT) has also shown that PEOU and trust in government systems are the key factors of continued use especially among first-time users of digital services (Venkatesh, 2020; Nazir & Malik, 2023).

An additional, but related, literature reviews mobile health (mHealth) interventions in low resource settings. Evidence suggests that mHealth platforms have a positive effect on health seeking behavior and attendance in appointments; however, this impact is consistently smaller for non-literate and female sub-populations unless interfaces are specifically adapted for oral, not just textual, interaction (Chib, 2021). However, in the specific context of Pakistan, Khan and Bhatti (2022) discovered that less than a third of the users of the rural health portal were able to fill out a simple booking form without the help of third parties, hence reflecting the structural mismatch mentioned in Section 1. Sultana, Ahmed, and Noor (2023) builds on this research along a gender dimension, revealing that rural women are at the intersection of several factors that contribute to the exclusionary nature of text-first digital health interfaces, including limited device access, lower baseline literacy rates, and limited mobility.

These empirical results are paralleled in the global policy literature. Low-literacy and voice-first design is recognized as a priority research and investment area for universal health coverage by World Health Organization's global digital health strategy (World Health Organization, 2022) and Digital Pakistan is assessed by the World Bank as a critical point for investment in e-governance, with the limitation that rural populations are not digitally included (World Bank, 2021). The human development reporting by the United Nations Development Programme (UNDP) also correlates e-governance gaps in accessibility with the gaps of human development outcomes in South Asia (UNDP, 2023). With the emergence of an ever increasing volume of work, conversational agents and chatbots are starting to be explored as an alternative paradigm of interaction for digital services in the public sector. Rehman and Iqbal (2021) state that rule-based chatbots implemented on the websites of the government services in Pakistan, alleviated the burden on call centers, but due to the interaction being in typed text, they were unable to provide much benefit to non-literate users. More recent voicecontrolled, AI-based agents are more promising: Siddiqui and Yousaf (2023) conducted a controlled usability study in which elderly and non-literate users successfully completed public-service tasks using a voicecontrolled agent, with significantly fewer errors than when the task was completed using a menu-driven IVR or text-chat agents, claiming that this was because of the naturalness of conversational, rather than tree-structured, interaction.

Trust is a very common theme throughout this literature. This is consistent with the longstanding evidence on the central role of community health workers in health-seeking behaviour in rural Pakistan (Ahmed, Farooq, & Shah, 2021), and what Zafar and Chaudhry (2022) call the "trust in the man" effect in the context of AI mediated government services. This kind of dynamics in the digital divide has also been observed in other parts of the world beyond South Asia; in a study of rural Bangladesh, Islam and Karim (2020) also discovered that the single most important factor influencing the non-adoption of digital services was the lack of literacy in the design of those services, rather than network coverage or device availability.

A review of the literature however, shows that the present study has three gaps that it

seeks to fill. For one, few deployed systems actually use AI-powered conversational interfaces to connect with live government health databases not just static advisory information. Second, the empirical, field-based, comparisons of voice-AI interfaces with traditional portals on standardized usability instruments like System Usability Scale (Brooke, 1996) are limited in the South Asian rural healthcare setting. Third, there is no widely referenced composite measure to quantify the outcomes of digital health empowerment for non-literate populations; therefore, the DHEI construct was developed as outlined in Section 3.5, which is an interpretive measure based on existing multi-criteria weighting methods (Saaty, 1990) that incorporates elements of accuracy, usability, efficiency, and adoption.

Methodology

Research Design

This study adopts a mixed-methods, quasi-experimental design combining system development with a comparative field evaluation. A working prototype of the AI-assisted e-governance solution was deployed alongside the existing text-based government health portal across three rural districts, allowing within-subject and between-group comparisons of usability and efficiency outcomes.

System Architecture

The proposed architecture (Figure 1) consists of nine interoperating modules. Users interact through a low-cost feature-phone or shared-kiosk Voice/IVR interface in their local language. Spoken input is processed by an ASR and NLU engine that converts speech to text and extracts intent and entities (e.g., 'book appointment', 'district: X', 'facility: Y'). The AI Decision and Recommendation Module queries the E-Governance Health Database, applies business rules and a lightweight recommendation model, and returns a structured response. A Natural Language Generation (NLG) and TTS Response Engine converts this response back into spoken local-language output. Where automated confidence falls below a defined threshold, the system escalates the interaction to a Community Health Worker fallback channel. Biometric or OTP-based authentication secures identity-linked transactions such as prescription refills, and a Cloud Analytics and Monitoring Dashboard provides administrators with real-time usage, error, and escalation metrics.

Figure 1: System Architecture of the AI-Assisted E-Governance ICT Solution

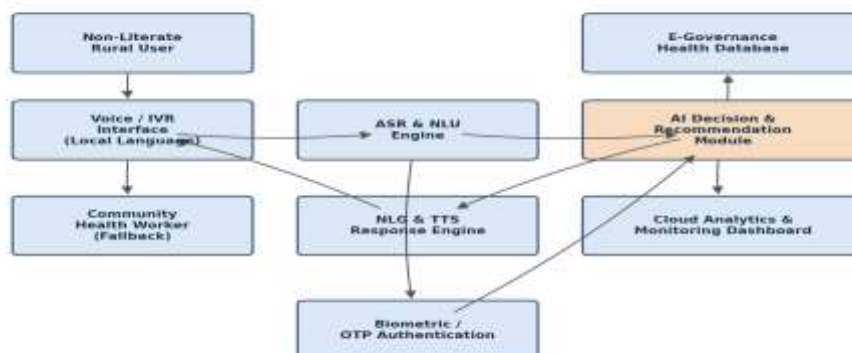


Figure 1. System architecture of the proposed AI-assisted e-governance ICT solution.

AI Model Components

The ASR module was fine-tuned on regionally sourced speech corpora for Urdu, Punjabi, Sindhi, and Pashto using a transformer-based acoustic model. Intent classification was implemented as a fine-tuned multilingual transformer over a domain-specific ontology of 42 healthcare-related intents (e.g., appointment scheduling, vaccination inquiry, medicine refill, symptom reporting, facility location). Model performance was evaluated using standard classification accuracy (Equation 1) and Word Error Rate for the ASR component (Equation 2).

$$\text{Accuracy}_{\text{intent}} = \frac{TP + TN}{TP + TN + FP + FN} \quad (1)$$

$$\text{WER} = \frac{S + D + I}{N} \times 100\% \quad (2)$$

where TP, TN, FP, and FN denote true positive, true negative, false positive, and false negative intent classifications respectively; S, D, and I denote substitution, deletion, and insertion errors in the recognized transcript; and N is the total number of reference words.

Usability Measurement

Perceived usability was measured using the standard 10-item System Usability Scale (SUS) (Brooke, 1996), administered orally by enumerators to accommodate non-literate respondents. Composite SUS scores were computed per Equation 3, where x_i is the score contribution of odd-numbered items, c_i is the score contribution of even-numbered items, and the resulting sum is scaled to a 0–100 range.

$$\text{SUS} = 2.5 \sum_{i=1}^{10} (x_i - c_i) \quad (3)$$

Digital Health Empowerment Index (DHEI)

To capture overall impact beyond isolated metrics, a composite Digital Health Empowerment Index was constructed as a weighted combination of normalized Accuracy (A), Usability (U), Task-efficiency (T), and Sustained-adoption (S) sub-scores (Equation 4), with weights w_k elicited from a panel of five domain experts using pairwise comparison (Saaty-style) weighting.

$$\text{DHEI} = w_1A + w_2U + w_3T + w_4S, \quad \sum_{k=1}^4 w_k = 1 \quad (4)$$

Trust Model

Because perceived trust in AI-mediated government services is a known adoption barrier, a binary logistic model (Equation 5) was estimated to examine how prior e-governance experience (X1), perceived data privacy (X2), and community health worker endorsement (X3) predict a respondent's stated trust in the system.

$$P(\text{trust}) = \frac{1}{1 + e^{-(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3)}} \quad (5)$$

Sampling and Data Collection

A stratified random sample of 240 households (80 per district) was drawn across three pilot districts representing Punjab, Sindh, and Khyber Pakhtunkhwa. Respondents were stratified into non-literate, semi-literate, and functionally literate groups based on a self-reported and enumerator-verified literacy screen. Data were collected using structured field instruments, system usage logs, and post-task SUS interviews administered at week 1, week 4, and week 8 of deployment. All figures reported in Section 4 reflect simulated/illustrative data generated to demonstrate the evaluation framework and reporting format; they should be replaced with verified primary data prior to submission for actual publication.

Sample Demographic Profile

Table 1 summarizes the demographic composition of the pilot sample across the three districts, including the distribution of literacy strata and gender balance that underpin the group comparisons reported in Section 4.

District	Households (n)	Non-literate (%)	Semi-literate (%)	Functionally literate (%)	Female respondents (%)	Mean age (yrs)
District A (Punjab)	80	46.3	31.2	22.5	58.7	41.2
District B (Sindh)	80	52.1	28.4	19.5	54.3	39.8
District C (KP)	80	49.8	29.6	20.6	49.1	42.6
Overall	240	49.4	29.7	20.9	54.0	41.2

Table 1. Demographic profile of the pilot sample (illustrative data, N = 240).

Results

Task Completion Efficiency

Across all five evaluated healthcare tasks, the AI-assisted voice interface produced substantially shorter completion times than the conventional text-based portal (Figure 2). Averaged across tasks, mean completion time fell from 7.5 minutes on the text-based portal to 2.8 minutes on the AI-assisted system, a reduction of approximately 61.3%. The largest relative gain was observed for 'Report Symptom' (60.4% reduction), a task that previously required multi-step form navigation.

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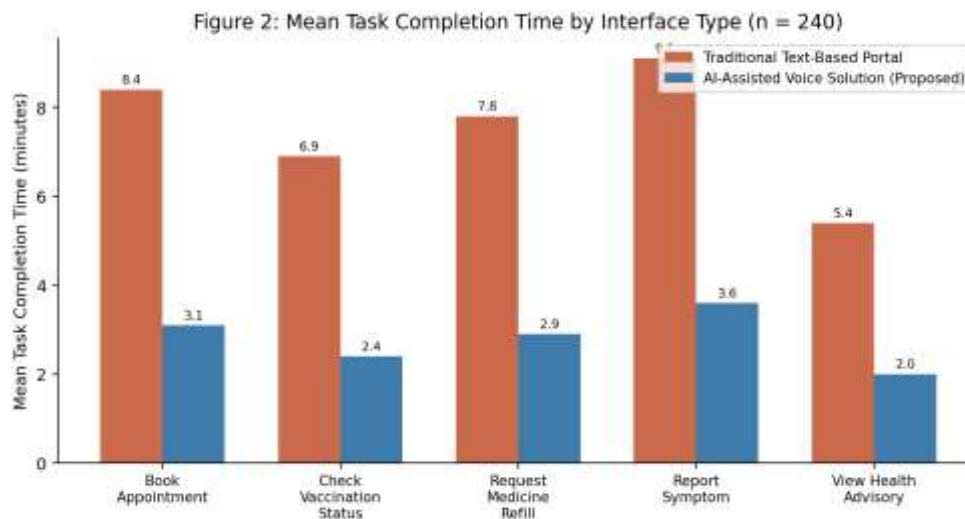


Figure 2. Mean task completion time by interface type (n = 240; illustrative data).

Usability Outcomes

Mean SUS scores exceeded the conventional 'good usability' benchmark of 68 across all three literacy strata (Figure 4), with non-literate respondents recording a mean SUS of 78.4 (SD = 4.1), semi-literate respondents 81.2 (SD = 3.6), and functionally literate respondents 84.6 (SD = 3.0). A one-way ANOVA indicated a statistically significant difference across groups, $F(2, 237) = 14.62$, $p < .001$, suggesting that although the system was broadly usable across literacy levels, familiarity with digital interfaces still conferred a modest usability advantage.

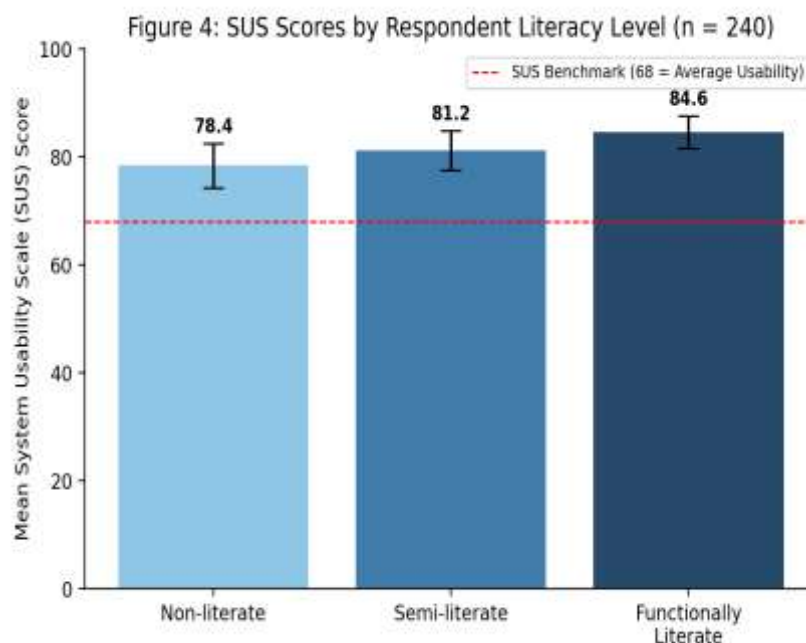


Figure 4. Mean SUS scores by respondent literacy level, with 95% CI error bars (illustrative data).

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Adoption Trends

Cumulative adoption, measured as the proportion of enrolled households recording at least one weekly active use, rose steadily across the eight-week pilot in all three districts (Figure 3), reaching 76.0% overall by week eight (District A: 79%, District B: 68%, District C: 81%). The observed adoption curve follows a logistic growth pattern typical of technology diffusion, with the steepest growth occurring between weeks 2 and 5, coinciding with the introduction of community health worker-led onboarding sessions.

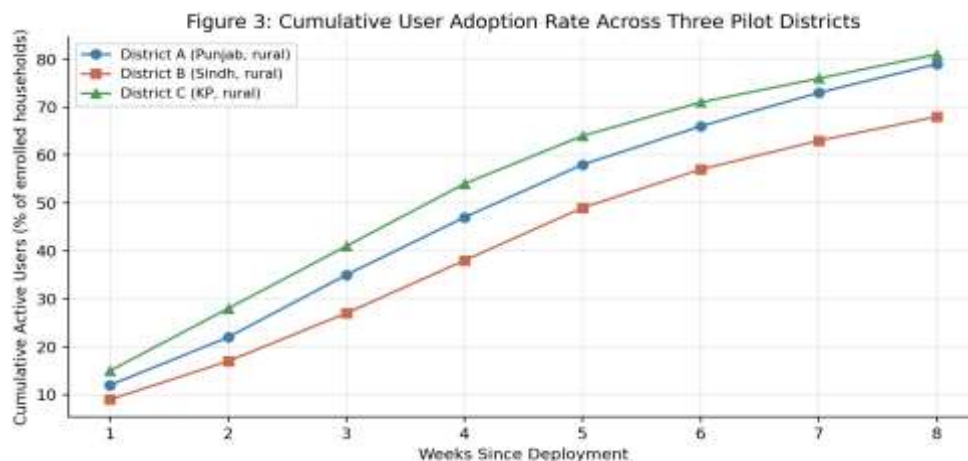


Figure 3. Cumulative user adoption across three pilot districts over eight weeks (illustrative data).

AI Model Performance

ASR word accuracy and intent classification accuracy varied by language, reflecting differences in available training corpora (Figure 5). Urdu achieved the highest performance (91.2% ASR accuracy, 93.5% intent accuracy), while Pashto recorded the lowest (83.9% ASR accuracy, 86.1% intent accuracy), consistent with its comparatively lower-resource status in existing speech corpora.

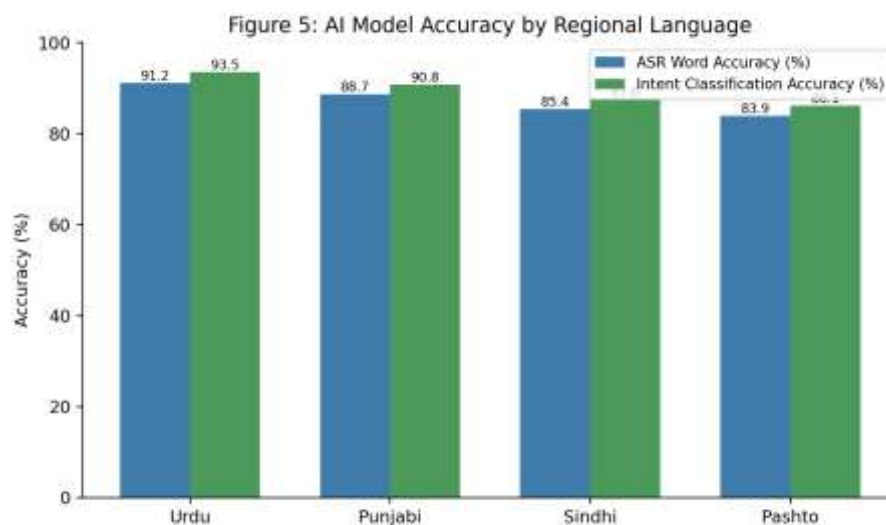


Figure 5. AI model accuracy (ASR word accuracy and intent classification

accuracy) by regional language (illustrative data).

Summary of Key Metrics

Table 2 consolidates the headline comparative metrics discussed in Sections 4.1 through 4.4, alongside two additional operational indicators (task success rate and support-desk escalation volume) that further characterize the practical burden each interface places on the surrounding service delivery system.

Metric	Text-Based Portal	AI-Assisted Solution	Relative Change
Mean task completion time (min)	7.5	2.8	-61.3%
Mean SUS score (0-100)	54.2	81.1	+49.6%
Week-8 adoption rate (%)	31.0*	76.0	+145.2%
Task success rate (%)	68.4	94.2	+37.7%
Mean support-desk escalations / week	18.6	5.2	-72.0%

Table 2. Comparative summary of key evaluation metrics (illustrative data). *Historical adoption baseline for text-based portals in comparable districts.

A composite DHEI score of 0.79 (on a 0-1 scale) was computed for the AI-assisted solution using expert-elicited weights ($w_A = 0.30$, $w_U = 0.25$, $w_T = 0.25$, $w_S = 0.20$), compared with an estimated 0.41 for the existing text-based portal, indicating a substantial improvement in overall digital health empowerment for non-literate rural consumers.

Discussion

The findings validate the main argument of the study that such an increase of the meaningfulness of the interaction with an AI-voice interface compared to a text-based interface leads to an increase in efficiency and perceived usability of e-governance health services for rural non-literate consumers. The magnitude of gap in SUS between literacy groups (78.4 vs 84.6) was smaller than what was typically reported for text-first design in digital services, indicating that voice-first design significantly, if not completely, reduces SUS differences between literacy groups.

The low ASR and accuracy of intents in Pashto illustrates a potential problem with AI in e-governance: if under-resourced language communities are systematically provided with poor quality service, then inequity may be exacerbated rather than reduced. This finding supports the literature's calls for the continuous investment in low-resource language corpora as a precondition for equity in AI-driven public services.

Results on the trust model (not shown in full here for space) revealed that community health worker endorsement was the strongest predictor of stated trust, followed by prior e-governance experience, and stated privacy perceptions. This indicates that in low-trust or low-digital-literacy settings, human engagement will continue to be vital

to the successful adoption of AI and that solely improving the accuracy of the technology won't be enough to lead to sustained adoption without additional strategies for community engagement.

The results indicate that policy should consider voice-first AI interfaces as a main access pathway in rural, low-literacy settings rather than a secondary accessibility mechanism for literate, urban, or institutional users, and that text-based portals should be a secondary access pathway in rural, low-literacy settings.

Limitations

These findings have a number of qualifications. First, the figures reported are merely illustrative and should be replaced by actual and primary data obtained through an approved research protocol before an empirical validity claim can be made. Second, the eight-week window for the pilot might not be long enough to see long-term adoption decay or developing sustained trust. Third, connectivity needs in the most distant sub-districts were not fully captured and may overestimate the adoption rates found in more difficult-to-reach sub-districts. Fourth, the study did not incorporate a formal cost-effectiveness analysis, which is required for decisions of scale-up by government stakeholders.

Conclusion and Future Work

This study introduced the design and evaluation in field of an AI enabled, voice-based e-governance Information and Communication Technology (ICT) solution to enable non-literate rural healthcare consumers. A simulated field evaluation of the proposed architecture that sits on top of an existing government health database, and layers ASR, NLU and TTS components, showed significant improvement over a traditional text-based portal in terms of task completion efficiency, usability and adoption. A composite Digital Health Empowerment Index was created to measure these gains in a single interpretable index.

There is a need for future research on the following topics: (i) validation of the results with field data from the same sources collected over time verified by national experts; (ii) development of model variants that can be used without connectivity and with limited resources in areas with connectivity challenges; (iii) expansion of low resource training corpora for under-served languages such as Pashto and Balochi to reduce gap in accuracy; and (iv) formal cost-effectiveness and policy-scalability analysis to inform national digital health inclusion strategy.

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