Design and Evaluation of a Mobile Medication Management System for Vulnerable Populations

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***Abstract*—Despite the rapid growth of mobile healthcare apps, many vulnerable populations such as older adults, those with cognitive impairments, and people in under-resourced communities are left behind due to limited digital literacy, outdated technology, or unreliable internet access. This paper introduces a mobile application designed to overcome these very challenges by simplifying medication management to foster independence. Our system reduces the cognitive and technical burden on users by allowing them to simply scan prescription labels, which automatically extracts crucial information, tracks inventory, and records dosage histories. It effectively manages stock by organizing medications based on expiration dates and streamlining the transition to new supplies. Built with Flutter and Dart for cross-platform support and FastAPI for backend operations, the app is optimized for low-resource environments and offline use. Ultimately, this solution aims to empower vulnerable populations, giving them greater confidence, autonomy, and efficiency in managing their own healthcare.**

***Index Terms*—Mobile Health, Accessibility, Medication Management, Low-resource Settings, Cognitive Support, Flutter, FastAPI**

I. Introduction

Mobile health (mHealth) applications have advanced rapidly over the past decade, providing functions that range from simple pill reminders to advanced monitoring of vital signs. These tools allow individuals to play a more active role in managing their own health, supporting adherence to treatment and encouraging self-care [1], [2]. Yet, despite their promise, access to and sustained use of such applications remain uneven. A digital divide persists that leaves many groups underserved, particularly older adults, people with cognitive impairments, and individuals in resource-limited settings [3]–[5].

For older adults, highly complex or feature-heavy applications often prove difficult to navigate. Concerns about data privacy, especially around sensitive information such as cardiac activity or sleep patterns, can further discourage use [3], [6]. Those living with cognitive impairments, including dementia, may find it especially challenging to keep accurate medication records; missed doses, accidental deletions, or inconsistencies are common [7], [8]. In parallel, users in under-resourced regions encounter structural barriers, such as intermittent internet access and reliance on outdated devices, which limit the usefulness of modern mHealth tools [1], [2].

A further limitation of many existing medication management applications is their reliance on manual data entry. Prescriptions, stock information, and dosage schedules must often be typed in by the user, a process prone to user error. This burden also reduces long-term engagement [9]. For example, Medisafe, one of the top three medication management applications on the Google Playstore requires users to set up an email account for backup, which can present a barrier for older adults or socioeconomically disadvantaged users [10]. MyTherapy, another of the top three, offers a smoother onboarding process but lacks optical character recognition (OCR) for automated prescription scanning and permits easy deletion of reminders, which can undermine adherence [11]. MedicaApp, the last application explored in this paper, provides a relatively broad feature set without requiring a login, but it similarly omits OCR and places the full responsibility for adherence on the user, with limited safeguards against mistakes [12].

The prototype presented in this study takes a different approach by emphasizing simplicity, security, and offline usability. Prescription labels can be scanned using OCR, allowing medication details to be auto-filled rather than manually entered [13]–[15]. Stock management is built in, with medications organized by expiration date to ensure smooth transitions between supplies currently in use and backup supplies. Dose confirmations remain manual in the current version, but planned upgrades include randomized verification codes designed to minimize mistakes, especially for users with cognitive impairments.

Security is a major part of the system's design [6]. Editing or deleting medication, stock, or dose records requires the user to correctly answer a security question, adding a safeguard against both accidental and intentional tampering. Planned future extensions include notifications to trusted contacts when doses are missed and the addition of a silent panic button for emergencies. The offline-first design ensures that users retain access to essential features even when connectivity is unreliable [1], [2]. Taken together, these design choices demonstrate an effort to create a medication management solu-

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tion tailored to vulnerable groups, combining usability, safety, and resilience to better support autonomous and confident self-management.

II. Related Work

Many widely used mobile health applications provide medication management functionalities, yet they frequently fall short of addressing the specific needs of vulnerable users. Common challenges include limitations in usability, security, and accessibility [1], [2], [9]. This section considers three widely recognized examples: Medisafe, MyTherapy, and MedicaApp.

Medisafe is a popular option, offering features such as reminders, adherence tracking, and refill alerts. Despite its comprehensive design, it exhibits notable limitations. Adding new medications requires an active internet connection, and the absence of optical character recognition (OCR) reduces accessibility for users with lower digital literacy. Moreover, the application permits multiple confirmations of the same medication within a single day [10], which could increase the risk of accidental overdosing and underscores the need for more robust safeguards.

MyTherapy supports dose logging, reminders, and stock tracking and is largely usable offline. However, it shares Medisafe's lack of a verification mechanism to prevent repeated dose confirmations [11], leaving it susceptible to user error. Additionally, all medication and stock information must be entered manually, a process that can be tedious and error-prone, potentially discouraging sustained engagement.

MedicaApp provides dose confirmation and refill reminders without requiring a login. While convenient, it does not include OCR scanning or secure editing features [12]. Its "untake" function, which allows users to undo a recorded dose, applies only to the current day's schedule, and offline performance has proven inconsistent in practice.

Collectively, these applications highlight recurring limitations: the absence of OCR for simplifying data entry, insufficient safeguards against duplicate dose confirmations, unreliable offline functionality, and limited protection against unauthorized modifications [1], [2], [9]. Beyond usability and functional limitations, security vulnerabilities in editing privileges have been documented in real-world settings, highlighting the potential for compromised adherence data. In particular, insufficient control over editing privileges can compromise the reliability of recorded information, as logs may be altered without accountability. Such vulnerabilities create the potential for misinterpreted adherence patterns—for example, stock depletion may appear excessive even when patients follow their prescribed regimen correctly. This could occur if external parties modify records to conceal medication diversion, leading to unnecessary clinical consultations, replacement prescriptions, and associated psychological and financial stress [16]. These concerns emphasize the need for robust security measures in medication management applications.

The system proposed in this study aims to address the recurring gaps identified in existing mobile health applications. It incorporates OCR scanning to automate medication entry, reducing the burden of manual input and improving accessibility for users with lower digital literacy [6], [13]–[15]. Secure protocols for dose confirmation are implemented to prevent duplicate or false confirmations, ensuring that adherence records remain accurate and trustworthy. Editing privileges are restricted and monitored to minimize errors, unauthorized modifications, and potential tampering, directly addressing concerns raised in prior studies [16].

Furthermore, the system is designed to operate reliably offline, enabling continued use in low-resource environments or areas with intermittent connectivity [5], [6], [13]–[15]. Planned enhancements include randomized verification codes to strengthen adherence and automated notification features for trusted contacts or caregivers, supporting real-time monitoring and timely interventions. Together, these features aim to improve not only the safety and reliability of medication management but also the overall usability and accessibility of the application for vulnerable populations, including older adults and individuals with cognitive or technological challenges. Additional long-term goals include integrating caregiver dashboards, visualizing adherence trends over time, and providing secure audit trails to support both patient safety and clinical decision-making.

III. System Design And Implementation

A. System Overview

The proposed mobile health application is built on a three-layer architecture, designed to provide seamless user interaction, efficient data handling, and secure information storage. This architecture consists of a mobile front-end for user engagement, a backend server for data processing, and a database for persistent storage [1], [2]. Users can add medications either manually or by scanning a prescription label. Once entered, medications are displayed as tiles on the dashboard, showing key details such as the name, dosage, frequency, and current stock levels [13], [15].

To streamline data entry, the application leverages optical character recognition (OCR) to extract text from prescription labels and automatically populate medication fields. Users are prompted to verify this information before it is recorded, helping to maintain accuracy and reduce errors [13]–[15]. The backend manages all data operations—including retrieval, insertion, updates, and deletions—to ensure consistency across the system [17]. Stock management features include low-supply alerts, automatic transitions between active and pending stock, support for partial doses, and the organization of future medication batches according to their expiration dates.

B. Modules and Components

Core modules include:

- Medication Management: Add, edit, delete medications; dashboard displays key details.

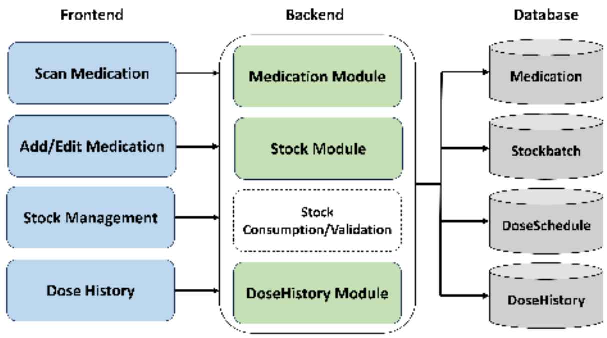

Fig. 1. Medication Management Application System Architecture.

- Stock Management: Tracks batches, expiry dates, and automates transitions.
- Dose Tracking and History: Confirms intake, decrements stock, logs doses.
- OCR Label Reader: Integrates Google ML Kit; uses AI fallback parsing to handle irregular formats [13], [15].

Future enhancements include alarms and notifications for trusted contacts.

C. Frontend Design

Built with Flutter and Dart, the frontend delivers a cross-platform, user-friendly interface [18], [19]. Flutter's single codebase ensures consistency across Android and iOS, while customizable widgets enable accessible layouts for older adults and users with cognitive impairments [3], [4]. Dart supports smooth interactions and fast updates, maintaining engagement. Overall, the framework balances usability, accessibility, and compatibility, making the prototype suitable for vulnerable populations in low-resource or variable-connectivity settings [1], [8].

- Dashboard: Displays medication tiles with color-coded stock levels.
- Medication and Stock Screens: Enable CRUD operations and dose confirmation; critical actions require security questions [16].
- Stock Management: Batches are ordered by expiry; soft deletion preserves audit trails; duplicates redirect to pending stock.
- User Protection: Editing/deletion gated by security questions to prevent unauthorized changes.

D. Backend Implementation

The backend, built with FastAPI, provides asynchronous RESTful endpoints for medications, stock, dose histories, and planned OCR parsing [17]. Its asynchronous design enables efficient request handling, while JSON exchange ensures seamless integration with the Flutter frontend and other health systems [2]. OpenAPI and Swagger UI streamline testing and documentation, and security is reinforced with CORS restrictions and input validation, with plans to add OAuth2/JWT for stronger protection [16]. FastAPI's lightweight, modular architecture makes it a reliable foundation for mobile medication management.

E. Database Design

The prototype uses SQLite with SQLAlchemy as a lightweight, file-based database that supports offline functionality and rapid development. SQLAlchemy enables structured queries and smooth integration with the Python backend, simplifying data management.

For production, PostgreSQL is planned for its scalability, reliability, stronger data integrity, and advanced security features, ensuring robust performance as the system grows and supporting potential integration with broader healthcare data systems. The core entities currently modeled in SQLite include:

- Medication: Stores prescription attributes.
- StockBatch: Tracks batch quantities, expiry, status, and soft deletion flags.
- DoseHistory: Logs medication intake linked to medication and batch.

One-to-many relationships ensure referential integrity; dose confirmation triggers automatic updates on stock and history.

F. OCR Label Parsing

The prototype uses Google ML Kit to extract text from prescription labels, displaying it for user confirmation [13], [15]. This reduces manual data entry, minimizing errors and cognitive load for older adults or users with impairments [3], [4]. By quickly capturing key details like medication names, dosages, and quantities, ML Kit improves efficiency in stock management and supports more accurate adherence tracking.

- Regex Parser: Structures dosage, frequency, quantity, and dates [15].
- AI Parser (Fallback): Handles irregular formats and improves accuracy.

This hybrid method enhances robustness. Future improvements include AI NLP, integration with standardized drug terminologies, and automated spelling correction.

G. Example Use Cases

When a user updates medication details, the Flutter frontend sends a PUT request to FastAPI. The backend validates, updates the database, and returns the revised record, and the dashboard refreshes automatically [18], [19].

When a user deletes a stock entry, the Flutter frontend issues a DELETE request to FastAPI. The backend triggers a security validation, applies a soft delete by flagging the record, and returns the updated inventory state. The dashboard then refreshes to exclude the deleted stock from totals while preserving the record for historical reference.

IV. Results

A. Prototype Achievements

The prototype effectively achieved its core objectives, allowing users to add, edit, and delete medications and stock records with ease. It also manages automatic stock adjustments whenever a dose is confirmed and maintains a dose history to help monitor adherence. Currently, the dose history operates reliably through backend API calls, while full frontend integration is still underway.

Key features such as alarms and notifications—including randomized confirmation prompts and alerts to trusted contacts—were planned in the original design but were not included in this version due to development limitations. Future iterations will aim to enhance functionality by enabling caregiver data sharing and emergency alert capabilities, further improving both safety and adherence support for users.

B. Demonstrated Workflows

Three representative workflows exemplify the system's operational behavior:

Workflow 1, Medication Addition to Dose Confirmation:

1) Medication entry creates a new database record.
2) Stock addition updates active and pending quantities.
3) Dose confirmation logs a new entry.
4) Stock decrements automatically; active batches switch to pending upon depletion.
5) Dashboard totals update immediately.
6) Dose history records both scheduled and actual intake times.

Workflow 2, Secured Medication Editing:

1) Follows Workflow 1 for initial addition.
2) Editing triggers a security question for validation.
3) Correct responses allow updates; invalid attempts are blocked.
4) Updated attributes persist in the database and dashboard.

Workflow 3, Secured Stock Soft Deletion:

1) Follows Workflow 1 for initial medication addition and stock entry.
2) Deletion request triggers a security question for validation.
3) Correct responses allow the stock record to be soft-deleted; invalid attempts are blocked.
4) The deleted stock remains in the database but is visually greyed out in the interface.
5) All related functions for the soft-deleted entry are disabled, preventing further interaction.
6) Dashboard and history totals are immediately updated to exclude the deleted stock from all calculations.

C. Testing Summary

Manual testing used a Samsung Galaxy S10+ with a local FastAPI backend and SQLite database. Evaluated features include:

- /medications returned correct JSON with computed stock totals.
- /stock accurately managed batches and adjusted stock.
- /dose_history reliably logged confirmed doses.
- OCR label parsing functioned but required manual corrections.
- System response times remained under one second.

Selected test cases are summarized in Table I.

D. Evaluation

- **Functionality:** Core features—including medication CRUD, stock management, secured editing, dose confirmation, and automatic stock updates—operated as designed. Security questions safeguarded critical operations.
- **Performance:** API response times were consistently <1 second; the frontend updated dynamically without page reloads.
- **Error Handling:** Soft-deleted stock items were greyed out; attempts to confirm doses when stock was completely depleted were prevented.
- **Limitations:**
  - OCR label parsing accuracy requires improvement to minimize manual correction effort [14], [15].
  - Dose history visualization at the individual medication level and soft delete function remain incomplete.
  - Alarm and notification functionality, including escalation to trusted contacts, has not yet been implemented.
  - The system currently lacks user feedback mechanisms to capture error reports or usability insights.

Screenshots for various functions are provided in Figure 2.

V. Discussion

The prototype demonstrates that a lightweight, offline-capable mobile application can effectively support medication management for vulnerable populations [7]. Core functionalities including medication and stock management, secure editing through a security question, dose tracking, and automated stock adjustments performed reliably during testing [1], [2]. These capabilities suggest that structured workflows can help reduce user errors, support adherence, and lessen cognitive burden for users who may struggle with complex digital interfaces. By automatically organizing stock based on expiration dates and distinguishing between active and pending batches, the system not only simplifies inventory management but also minimizes medication waste, which is critical in settings with limited resources [5], [7], [9]. The soft deletion mechanism further enhances data integrity by retaining records of removed stock, providing an audit trail and promoting accountability when caregivers are involved in medication management [6], [16].

The integration of optical character recognition for prescription label entry shows significant potential to streamline data entry and reduce manual input errors [13]–[15]. Users can quickly capture prescription information, which is automatically parsed into the appropriate fields. While this functionality requires manual verification to ensure accuracy, it nonetheless represents a substantial improvement in usability, particularly

TABLE I
TEST CASES

Test Case	Input	Expected Output	Actual Output
Add Medication	Name: "Augmentin", Dosage: 500 mg	Medication saved; JSON returned with ID and total stock = 0	Matches expected JSON
Confirm Dose	Medication ID: 1, Quantity: 1	DoseHistory entry created; active stock decremented; totals updated	Matches expected output; stock totals updated correctly
Delete Medication	Medication ID: 1, Security answer correct	Medication removed; all related stock batches deleted; frontend updated	Matches expected behavior
OCR Parsing	Prescription label image	Medication fields autofilled	Parser requires fine-tuning; manual correction needed

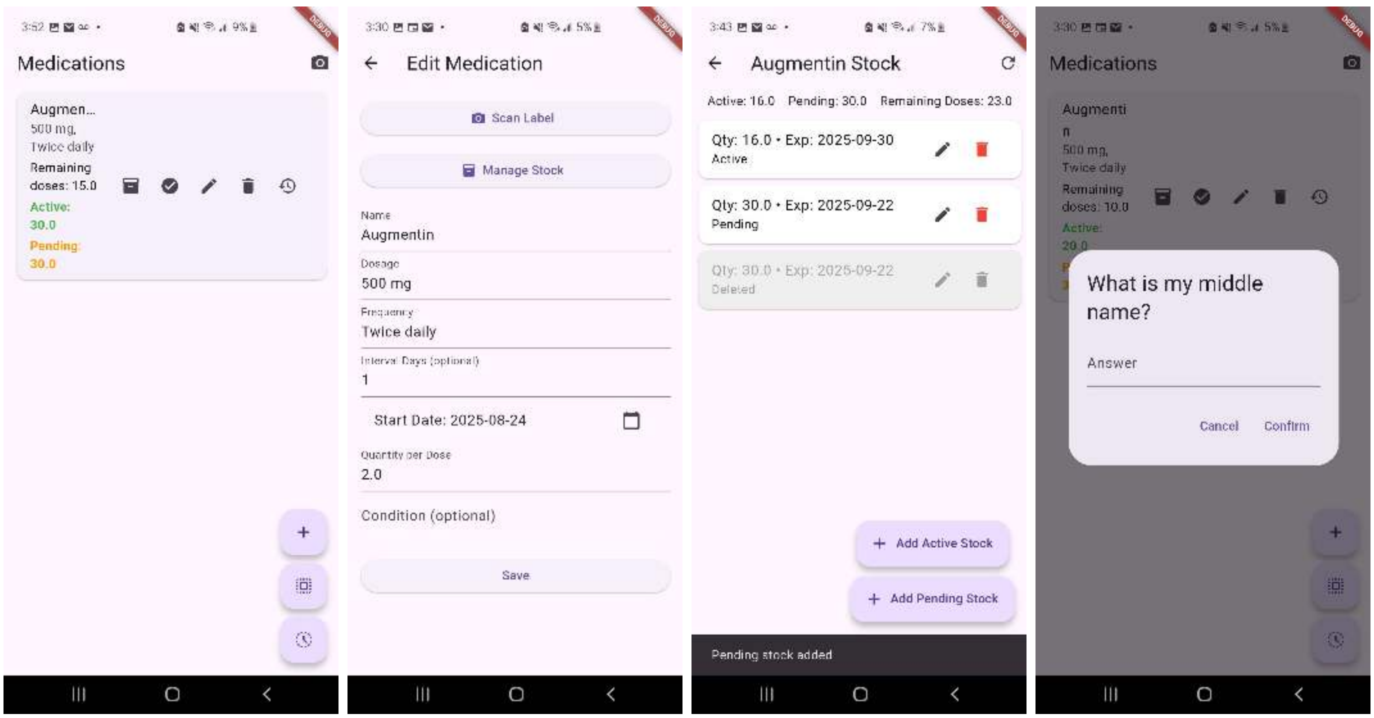

Fig. 2. Dashboard showing (from left to right): active medication and stock levels, OCR-Based medication entry screen, management screen showing pending stock with expiration dates and remaining doses, security question prompt.

for older adults or those with cognitive impairments [3], [4] who may find repeated manual entry cumbersome. This capability also aligns with trends in digital health, where automation of routine tasks has been shown to reduce cognitive load and improve adherence among vulnerable populations [4], [20].

Compared with widely used commercial applications such as Medisafe, MyTherapy, and MedicaApp, the prototype demonstrates distinct advantages. Unlike Medisafe, which requires a continuous internet connection and manual stock management, the prototype operates largely offline and automates stock updates [10]. MyTherapy provides offline functionality but lacks OCR capabilities and safeguards against erroneous dose confirmations [11], while MedicaApp similarly lacks both OCR and secure editing features [12]. In addition, the soft deletion mechanism in the prototype preserves deleted records, offering an audit trail and enhancing accountability, which is particularly important when caregivers are involved in medication management [6], [16]. These features collectively reduce the risk of accidental or unauthorized modifications and ensure that adherence and stock data remain reliable, supporting clinical and personal decision-making.

Despite these strengths, several limitations remain. OCR autofill accuracy is variable and can still require manual correction, while frontend visualization of dose history is not yet fully implemented. Essential adherence-support features including alarms, notifications, and caregiver sharing are absent from the current prototype [9]. Although the system handles edge cases such as complete stock depletion by disabling interaction buttons, additional safeguards and automated alerts could further reduce user errors. Future improvements may include AI-assisted OCR parsing [6], [15], more comprehensive authentication protocols, notifications to trusted contacts, and emergency alert functionalities. Incorporating these enhancements will be critical to ensure the system not only meets its technical objectives but also aligns with the practical needs of its target users.

Overall, the results indicate that an application with automated stock management, OCR-assisted medication entry, and built-in security can meaningfully support older adults, individuals with cognitive impairments, and those in low-resource settings [3], [7], [9]. By providing a structured, user-friendly interface and offline-first functionality, the system has the potential to increase adherence, reduce errors, and empower users to take a more active role in managing their health [4], [20]. These results suggest that even lightweight, offline-capable applications can provide robust support for vulnerable populations while laying the groundwork for future enhancements that integrate AI, caregiver support, and comprehensive adherence monitoring.

VI. Conclusions and Future Work

This paper presents the design, implementation, and preliminary evaluation of a mobile medication management application specifically developed for older adults, individuals with cognitive impairments, and users in low-resource settings [3], [7], [9]. The prototype demonstrates the feasibility of a cross-platform, offline-capable system that integrates automated stock management, OCR-assisted medication entry, and security safeguards to support independent and safe medication management [6], [13]–[15].

Compared with existing commercial solutions [10]–[12], the application offers several advantages. The offline-first design allows reliable use in environments with unstable internet connectivity, while automated stock management and organization by expiration date improve safety and reduce waste. OCR-assisted medication entry reduces the cognitive burden of manual data input, particularly for users with limited digital literacy. Security mechanisms, including controlled editing and soft deletion, provide accountability and protect against accidental or unauthorized changes to medication and stock records [8], [16].

However, there are limitations. OCR accuracy is not yet consistent [13], frontend dose history visualization is incomplete, and adherence-support features such as notifications and caregiver sharing have not been implemented [9]. Testing has so far been confined to manual and localized instances. Addressing these limitations will require further development, including AI-assisted OCR parsing, integration of standardized medication ontologies [6], [15], expanded authentication protocols, and the addition of notifications and emergency alert systems.

In summary, this prototype demonstrates that a lightweight, automated, secure, and accessible mobile application can effectively address medication management challenges faced by vulnerable populations. With continued enhancements and comprehensive usability testing, such a solution has the potential to empower users to manage their medications safely, independently, and with greater confidence [3], [7], [9].

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