QR Code-Based Multilingual Medicine Expiry Alert System for Enhanced Patient Safety a Conceptual Framework and Preliminary User Awareness Study

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***Abstract*—Background: Over use of out-of-date medicines remains a poorly-addressed public health problem, especially in LMI countries where small printed labels and lack of health literacy, functional vision, and language proficiency are risk factors for unsafe medicine use.**

Objective: With this in view, this study was a conceptual analysis to present a multilingual medicine expiry alert system using QR code as a digital health solution to supporting patients to access timely, clearly presented and language-appropriate medicine expiry information. It also explores the users' awareness of medicine expiry dates, expiry-checking behaviour, technology readiness and initial intention regarding this proposed system.

Methodology: The Methodology was descriptive, cross-sectional survey of 50 respondents using purposive sampling technique. A structured questionnaire consisting of 15 items was developed on medicine expiry awareness, expiry checking, smartphone ownership, qr code familiarity and willingness to adopt the technology and data collected. This medicine QR code-based system would feature a secure and cloud-based medicine database, a translation module with TL-English validation by pharmacist and covering at least 5 languages, a mobile app interface, and a push-notification system, which would proactively alert the users when the medicine is about to expire etc. Expert validation of content was acceptable and internal consistency was good, Cronbach alpha = 0.74. Descriptive statistics and chi-square tests were used for data analysis and effect size was determined via Phi and Cramer's V.

***Index Terms*—digital health, medicine expiry, multilingual health communication, patient safety, QR code.**

I. INTRODUCTION

Global priority medicine safety is a global public health issue. The World Health Organization (WHO) calcinates harm caused by medication use as nearly 50% of all preventable harm in health care worldwide, and the main causes of this harm are among the following: inadequate understanding of labels, poor system of supply chain and limited health literacy (WHO, 2019; Donaldson et al., 2017). Additionally, multilingual communities, as well as an inefficient pharmaceutical supply chain, in lower income communities compound the issues on expired medicine consumption (Nkansah et al., 2010; Osemene & Lamikanra, 2012).

The various types of risks associated with the disposal of discarded drugs can include loss of effectiveness, dangerous breakdown chemicals, or drugs that become toxic. The degradation of tetracycline antibiotics is well known for forming nephrotoxic compounds (Frimpter et al., 1963). However, it is still not enough at the population-level, especially among people with lower levels of literacy, rural residents, and elderly people (Gidey et al., 2019).

Quick Response (QR) codes have become a very low cost, high convenience digital "link" from offline to online information system. QR codes have also been used in healthcare for patient identification, accessing medical records, vaccine verification, and drug authenticity verification (Faggiano et al., 2021; Joshi & Sawant, 2024). However, there is no peer reviewed literature to explore their application specifically for alerting about medicine expiry data in pro-active approach and communicating the same in multilingual approach.

This research is therefore aimed on a conceptual framework called Medication Expiry Date Alerting System using QR code and preliminary survey was carried out to gauge user awareness and acceptance. Specific Objectives are:

• To assess the current awareness and self-reported behaviour of checking the expiration date on medicines.

• To understand the prevalence of smartphone ownership and QR-code familiarity, which is important to understand for digital health adoption.

To assess the willingness to use QR code based multilingual expiry alert system.

•To investigate possible relationships between sociodemographic factors and technology acceptance.

• To present a conceptual system architecture of a system based on QR for medicine expiry alert in multiple language.

II. LITERATURE REVIEW

2.1 Expired Medicine Use: Prevalence and Consequences

It has been documented that expired pharmaceutical products are a public health issue in a variety of settings. A community-based survey in Ethiopia, conducted by Gidey et al., (2019) revealed that 42.5% of the households kept expired medications and 28.3% of them used the expired medication. One of the key studies on home medicine storage practices reported a substantial percentage of household heads in the LMICs store medicine past their expiration dates and the main reason for this is the lack of understanding of the instructions on the labels (Osemene & Lamikanra, 2012; Davis et al., 2006). The degradation products themselves may be toxic as, for example, in Fanconi's syndrome caused by degraded tetracyclines (Frimpter et al., 1963).

2.2 Medicine Label Comprehension and Literacy Barriers

Health-literate patients were significantly more likely ($p<0.001$) to accurately read medications labels and find the expiration date as shown by Davis et al. (2006). Countries with high linguistic diversity may have medicine labels which are only available in the official language(s), and blockchain technology has the potential to make them accessible to a substantial population (Schwei, et al., 2016). Medication errors and non-adherence are related to the lack of information in native language about medicines (Schillinger et al., 2002).

2.3 QR Codes in Healthcare

QR codes are 2-D matrix codes that can be read by any state-of-the-art smartphone camera (Denso Wave, 1994). QR codes have been used in the clinical environment for patient identification wristbands, surgical equipment tracking, vaccine certificate verification and patient education (Faggiano et al., 2021, Joshi & Sawant, 2024 and Mohsin et al., 2024). As mentioned in the previous studies, QR codes identified by Karia et al., (2019) have been seen as a tool effective in-patient education in the nursing field. Early use studies of the QR code in healthcare education (Karia et al., 2019) showed that its use is increasing, and a more recent comprehensive review (Joshi & Sawant, 2024) revealed that its applications range from the education sector to clinical applications across 30 studies. Faggiano et al. (2021) performed a systematic scoping review (SSR) finding that QR codes are increasingly used in the medical field to collect data, provide educational content, or deliver information related to the therapy/surgery that is performed. Their findings substantiate the pertinence of QR codes as useful online solutions in health systems while noting that the applications in cardiology are limited.

2.4 Digital Health Adoption and Technology Acceptance

According to the Technology Acceptance Model (TAM) (Davis, 1989), the perceived usefulness and ease of use of the information technology (IT) are the main reasons that individuals accept it. As of December 2023, there were about 5.6 billion mobile subscribers worldwide (GSMA Intelligence, 2024), and 4.7 billion mobile internet users (GSMA Intelligence, 2024), providing a smart platform for conducting QR-based health interventions. Being familiar with the technology and feeling that it is beneficial to health are positively correlated with user acceptance of digital health tools (Venkatesh et al., 2012).

2.5 Research Gap

There are healthcare QR code applications already in place, most of which focus on drug validation, patient identification, and information retrieval at dispensing. None of the studied studies have offered a pro-active solution to warn the patient before the drugs expire; none of the studies remove multilingual communication dynamically; none of the studies connect to a live cloud database; and no pro-active solution to warn patient before drugs expire, that integrates multilingual communication dynamically, and that links to a live cloud database, was proposed in a mobile application framework.

III. METHODOLOGY

3.1 Study Design

Descriptive cross sectional survey design was used. This design can be used when things need to be measured only once, to look at the prevalence of awareness, behaviour and attitudes at one point in time. (Kesmodel, 2018) The study was conducted as an initial study to provide the base line data for an upcoming prototype development and evaluation study.

3.2 Population and Sampling

The target population was adult (18 years old) consumers who had used or bought retail prescription or OTC products in the last year. The sampling method used was non-probability sampling, namely purposive sampling which consisted with the respondents who had direct experiences in using medicines, so that the data that emerged from respondents could be relevant to the study. The recruitment was to be carried out offline using offline distribution channels at community pharmacies and online using on-line distribution through institutional channels. Fifty participants were enrolled, a sample size suitable to support a preliminary pilot investigation to the ultimate end of estimating effect size and feasibility of conducting a full-scale investigation (Johanson & Brooks, 2010; Browne, 1995). Caution should be taken to interpret the results as exploratory, as the study does not have population-level representativeness. All participants completed a written informed consent after obtaining ethical approval from the institutional review board before data collection. The participation was voluntary and anonymous.

3.3 Instrument Development and Validation

A structured self-administered questionnaire was designed using four parts (a) Sociodemographic profile; (b) medicine expiry awareness and behaviour 05 items; (c) Technology access and awareness 03; (d) Medicine adoption willingness and perceived utility 05. The content was validated with expert opinions of two pharmacists and one digital health expert. The Cronbach's alpha for the two subscales (awareness and adoption) was 0.74 obtained from a pilot test of 10 participants, which is acceptable (Tavakol & Dennick, 2011).

3.4 Data Analysis

Frequency counts and percentages were calculated for all variables. To explore relationships between key categorical variables and willingness to adopt, chi-square ($\chi 2$) tests of independence were used with $p < 0.05$ set as the level for statistical significance. Before performing Chi-square tests the following assumptions were checked: None of the cells had an expected cell frequency of less than five. Fisher's exact test was used as appropriate in places where cells with expected counts < 5 occurred. Effect sizes Phi (φ) and Cramér's V were calculated to reflect the practical size of significant relations (Cohen, 1988). IBM SPSS Statistics Version 27.0 (IBM Corp., Armonk, NY, USA) was used for all analyses.

IV. PROPOSED SYSTEM ARCHITECTURE

4.1 System Overview

Our QR Code-Based Multilingual Medicine Expiry Alert System (QR-MMEAS) provides a combination of five interactive modules: (1) a QR code generation and application module, (2) a cloud-based pharmaceuticals database, (3) a module responsible for multilingual translations and display, (4) a mobile application interface for end user and (5) a notification and alerting module.

Table I Conceptual Architecture of The Qr-Mmeas

Component	Description	Technical Implementation
QR Code Module	Unique codes generated per	QR generation API; linked to

	batch; affixed to packaging	product record
Cloud Database	Stores product name, batch no., manufacture/expiry dates	MySQL/PostgreSQL; AES-256 encrypted cloud hosting
Multilingual Module	Translates information into user-selected language	Pharmacist-validated DB (5 languages); API fallback
Mobile Application	QR scanning, medicine cabinet, display in user language	Cross-platform Android/iOS; user account system
Notification Engine	Push alerts 30, 7, and 1 day(s) before expiry	Firebase Cloud Messaging; configurable intervals

4.2 System Workflow

1. The medicine product manufacturer/pharmacist register the product in the cloud database with made in batch and expiry information.
2. Packaging is stamped with a unique QR code that is connected to a record of the product.
3. The Patient scans the QR code with QR-MMEAS mobile application.
4. System fetches the product record, and presents the details in the language chosen by the user.
5. User stores medicines in his/her medicine cabinet in the app.
6. Notification engine pushes alerts 30 days, 7 days, and 1 day(s) ahead of time.
7. At the end of the validity, the system identifies the medicine and recommends for appropriate disposal.

4.3 Multilingual and Security Design

Multilingual support operates on a 2-step system: a pharmacist verified translation database (Tier 1) to support safety critical information in the 5 core languages as well as a cloud Translation API fallback (Tier 2) for extended coverage. When content is provided using machine translation, users are alerted to this. The two-tier approach is based on QR based systems that have proven successful during COVID-19 (Udugama et al., 2020). Security comes with the added layers of AES-256 encryption, HTTPS communication through API, QR code digital signatures, two-factor authentication and role-based access control, as per data protection regulations (GDPR, PDPA).

V. RESULTS

5.1 Demographic Profile of Respondents

Total of 50 respondents filled the questionnaire. Figure 1 represents the demographic profile in terms of gender, age group, education achievement and occupation. The detailed frequency distribution of all the demographic and outcome variables is presented in Table 3.

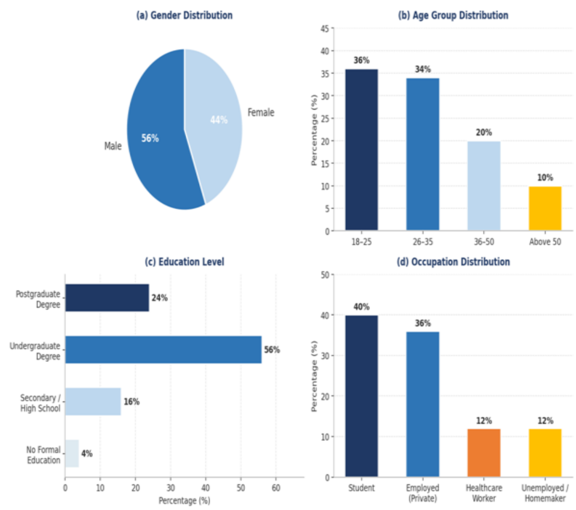


Figure 1. Demographic Profile of Respondents (n = 50)

The sample was predominantly male (n = 28; 56%), aged 18–35 years (n = 35; 70%), and educated to at least undergraduate level (n = 40; 80%). The largest occupational group within the sample were students (n = 22, 44%), followed by those in the private sector (n = 14, 28%) and those working in government (n = 8, 16%). Eight percent (n = 4) of the respondents were healthcare workers. This profile represents a typical group of digitally literate population segments but it was important to take this into account when analysing the adoption willingness.

5.2 Medicine Expiry Awareness and Behaviour

Fig. 2 shows the proportion of people who checked the expiry-date at least once before using the medicine (Fig. 2a), and the distribution of the level of awareness to the risk of taking outdated medicine (Fig. 2b).

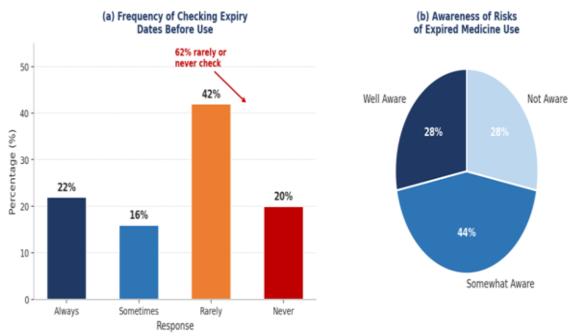


Figure 2. Medicine Expiry Awareness and Behaviour (n = 50)

When asked about checking the expiry date of medicines before use, the majority (62%, n = 31) respondents reported rarely (some of the time) or never (occasionally/never) doing this, whereas only 22% (n = 11) reported "always" checking the expiry date of medicines. 16% (n = 8) reported checking sometimes. This result corroborates that of the literature on non-compliance to low expiry checking in the community (Gidey et al., 2019; Osemene & Lamikanra, 2012). 72% (n = 36) respondents expressed a level of awareness of risk with expired medicines (including 40% well aware and 32% somewhat aware) but this was lacking in terms of consistent checking behaviour, highlighting the awareness-behaviour gap to be addressed by the proposed notification system. This deficit is theoretically consistent with the Health Belief Model, which suggests that just the knowledge does not lead to prevention action, unless there is a proximal cue to action (Rosenstock, 1974).

5.3 Technology Access and QR-Code Familiarity

Figure 3 presents smartphone ownership (panel a), QR-code familiarity (panel b), and comfort with scanning QR codes (panel c).

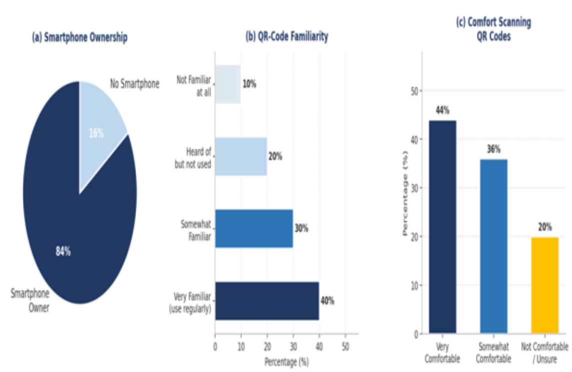
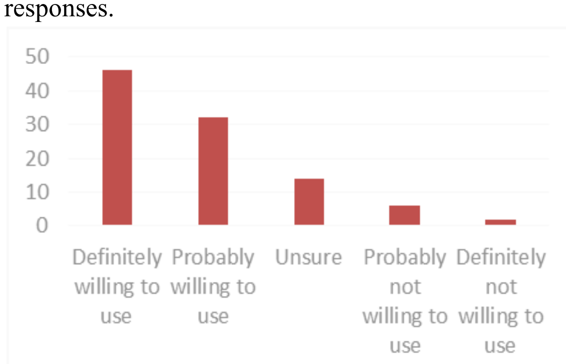


Figure 3. Technology Access and QR-Code Familiarity (n = 50)

Almost every telephone owner (84%, n = 42) used a smartphone, and 70% (n = 35, 30% very familiar and 40% somewhat familiar) were at least somewhat familiar with QR codes. 76% reported being comfortable at using scanning QR codes (34% and 42% very comfortable and somewhat comfortable). These results suggest that the technology that underpins a QR based health intervention is largely available in this sample. But, there was a small number of participants who did not use a smartphone (16%, n = 8) as well as those who didn't know what QR codes were (10%, n = 5) and these should be the ones that are excluded from the proposed system by future implementation works so that inclusive designs can be undertaken.

5.4 Adoption Willingness

But for that purpose, it is better to set up a stacked bar chart of the distribution of willingness to use the QR-based expiry alert system, as shown in Figure 4, thus allowing immediate comparison between the proportions of positive, neutral, and negative responses.



1. Figure 4. Willingness to Adopt the QR-Based Expiry Alert System (n = 50)

A total of 78% (n = 39) were willing to use the proposed QR based system (46% definitely willing and 32% probably willing). Only 8% (n = 4) were unwilling (4% probably not willing; 4% definitely not willing) and the others 14% (n = 7) undecided. The level of acceptance is similar to the reported rate of willingness of adoption of the mHealth technology in similar community health technology studies (Venkatesh et al., 2012; Akter & Ray, 2010). The minority stating unwillingness raised issues around the dependency of smart phones and the security aspects of using them to store data, which were directly explained in the design of the security, as presented in Section 4.3.

5.5 Statistical Association Analysis

Table 2. Chi-Square Test Results: Associations with Adoption Willingness

Independent Variable	Chi-Square Value	df	p-Value	Effect Size (φ)
QR-Code Familiarity	8.42	1	0.004*	φ = 0.41*
Education Level	5.17	2	0.075	V = 0.23
Smartphone Ownership	6.83	1	0.009*	φ = 0.37*
Age Group	3.21	3	0.360	V = 0.18
Gender	0.94	1	0.332	φ = 0.14

The results of the chi-square analysis showed that familiarity with QRcodes (χ^2 = 8.42, df = 1, p = 0.004, φ = 0.41, medium to large effect) and smartphone ownership (χ2 = 6.83, df = 1,p = 0.009, φ = 0.37, medium effect) were statistically significant factors when considering adoption of QRcodes. There were no significant differences among three background factors education level, age group and gender in adoption willingness (Table 2). For significant associations, all chi-square assumptions (minimum expected cell frequency ≥5) were met. These medium to large effect sizes suggest that those relationships are not only statistically measurable, but practically meaningful, for the impact of technology familiarity and smartphone ownership. These results suggest that in this sample it is technology familiarity itself that is the biggest predictor of openness to QR-based health solutions, rather than certain sociodemographic characteristics alone, which corroborate the studies by Davis (1989) and Venkatesh et al. (2012) on Technology Acceptance Model (TAM) and Unified Theory of Acceptance and Use of Technology (UTAUT).

VI. DISCUSSION

This study filled a specific niche as not much work has been done so far in the field of medicine safety pre-expiry notifications via QR codes and in other languages apart from English. The survey results offer conceptual framework in terms of acceptability of the system and factors relating to showing interest in the adoption.

The community-level studies in similar contexts (Gidey et al., 2019; Osemene & Lamikanra, 2012) found a similar 62% of the respondents rarely or never check for medicine expiry dates. The awareness-behaviour gap is theoretically explained by the Health Belief Model (Rosenstock, 1974) suggesting that knowledge alone does not influence behaviour with respect to preventive health measures without external cues to action. The proposed notification system is, in theory and practice, a strategic way of directly targeting the cue-to-action component, with the provision of timely and proactive pre-expiry notification.

The results show that there was a strong relationship between the willingness to adopt the QR code and both smart phone ownership (χ^2 = 6.83, p = 0.009, φ = 0.37) and familiarity with the QR code (χ^2 = 8.42, p = 0.004, φ = 0.41), confirming the prediction of TAM that people who have experience with technology are more likely to accept it because they perceive it as less complex (Davis, 1989). Effect sizes were found in the medium to large range and gives the statistical significant correlations greater confidence. Results indicated that demographic variables (age, gender, education) were not significant, potentially suggesting that access to technology, as opposed to demographic profile is the most critical factor to adoption, with implications for practical deployment: a literacy campaign that focuses on QR Codes and encourages community access to technology can be more effective than demographic targeting approaches. This aligns with UTAUT which suggests that social influence as well as facilitation conditions are important aspects of adoption (Venkatesh et al., 2012).

The proposed QR-MMEAS is unique on three fronts: (a) in that it seeks to alert proactively as opposed to passive information retrieval in the current QR-based healthcare applications; (b) it focuses not only on automated machine translation but also prioritizes using pharmacist-validated translations; and (c) it aims to be used by consumers at the end of the healthcare supply chain as opposed to being used for regulatory authentication.

There are a number of caveats that need to be noted. This study had a small sample size (n = 50) from a relatively digital literate population, which therefore may not reflect the general population. It is still a concept and has not yet been implemented or tested. All data are self-reported from the surveys. The future studies should focus on prototype development, usability testing, and on thorough experimental testing and validation of patient safety outcomes.

VII. LIMITATIONS

1. Sample size (n=50) is too small to be representative of the entire spectrum of medicine users, especially elderly, rural and low literacy users who are most at risk.
2. The QR-MMEAS is a conceptual framework. No evidence of usability, performance or patient outcome data exist. Any reference to a possible impact will be conditional on successful implementation, validation.
3. Recall bias and social desirability bias exist in all data.
4. Cross sectional design: Offers a picture at a point in time and does not necessarily lend itself to causal explanations.
5. PPPB system is depended on smart phone, internet but eliminating people who do not have these resources.
6. The first validated database is only in 5 languages, may be too limited for settings with a high level of diversity.

VIII. CONCLUSION

In this study a conceptual QR Code-Based Multilingual Medicine Expiry Alert System (QR-MMEAS) has been proposed and a preliminary survey to evaluate the empirical location of the system has been done. Survey results found that although respondents know of some risks associated with failing to check expiry dates on medicines, 62% of them do not do so regularly. The level of smartphone ownership and familiarity with QR-codes (84% and 70% respectively) indicates that the proposed approach is technologically feasible. Interested in adopting 78% of respondents but this was found to be correlated with technology familiarity and not with demographic variables.

The study explicitly cautions that it offers “suggestive” conceptually and “exploratory” empirically evidence of patient safety improvement, and implies that none of its suggestions in this paper is guaranteed to be effective by itself. The design of the system is still at the conceptual level. More work is needed in the future involving the prototype, expert usability evaluation, and pilot clinical testing, as well as formal experimental testing to determine impact on patient safety.

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