International Journal of Science Annals, Vol. 7, No. 2, 2024
print ISSN: 2617-2682; online ISSN: 2707-3637; DOI:10.26697/ijsa

SOCIAL AND BEHAVIORAL SCIENCES. Health Care Sciences

ORIGINAL RESEARCH

A Persuasive Technology mHealth Self-Monitoring System for Intervention in Diabetic Patients Medical Adherence

Authors' Contribution:
A – Study design;
B – Data collection;
C – Statistical analysis;
D – Data interpretation;
E – Manuscript preparation;
F – Literature search;
G – Funds collection

Kgasi M. R.[1 ABCDEF], **Chimbo B.**[1 AEF], **Motsi L.**[1 ACEF]

[1] *University of South Africa, South Africa*

Received: *14.06.2024;* ***Accepted:*** *23.07.2024;* ***Published:*** *25.12.2024*

Abstract

Background and Aim of Study: *The prevalence of chronic diseases like diabetes has caused unmeasurable strain on many health systems especially in developing countries. Chronically ill patients are traumatised by their incurable illnesses, which adversely affects their adherence to their medical treatment, resulting in serious complications and even death. The aim of the study: to implement an intervention mobile health (mHealth) system by integrating persuasive technologies into mobile applications to empower diabetic patients to adhere to medical prescriptions.*

Material and Methods: *Fogg Behaviour Model (FBM) was leveraged for the integration of mHealth and behaviour aspects. The system was developed with Kotlin programming using the Android Studio working integrated development environment (IDE). Tools including Firebase Real Time Database, Android Studio and Android Mobile Phone were used to afford a fully fledged mHealth self-monitoring system. The system was evaluated using descriptive statistics by medical personnel and social workers to determine the completeness, clarity, logical arrangement, correctness, reliability, usability, as well as content validity.*

Results: *Findings indicated that the mHealth system meets a good degree of the measures that inform patients' self-monitoring for medicine adherence. The evaluation results also suggested that some functionality of the mHealth self-monitoring system requires an incremental improvement, to provide a seamless healthcare support. The artefact was descriptively evaluated on seven parameters: completeness that showed a mean of 3.75 with a standard deviation of 1.070; functionality with a mean of 4.05 and standard deviation of 0.945; accuracy with a mean of 3.70 and standard deviation of 1.031; reliability a mean of 3.90 and standard deviation of 0.945; consistence a mean of 4.00 and standard deviation of 0.968; performance a mean of 3.75 and standard deviation of 1.250, and usability with a mean of 3.55 and standard deviation of 0.999.*

Conclusions: *The developed system is as effective as face-to-face consultations and personal visits to healthcare facilities. Diabetic patients need to adhere to medicine to avoid further complications that could lead to death.*

Keywords: *diabetes, mHealth, self-monitoring, medical adherence, persuasive technology, chronic diseases, remote healthcare provision.*

DOI: *https://doi.org/10.26697/ijsa.2024.2.2*

Conflict of interests: *The authors declare that there is no conflict of interests*

Peer review: *Double-blind review*

Source of support: *This research did not receive any outside funding or support*

Information about the authors:
Kgasi Mmamolefe Rosina *(Corresponding Author) – https://orcid.org/0009-0006-7366-9196; 10151133@mylife.unisa.ac.za; Doctor of Philosophy in Information Systems, University of South Africa, Johannesburg, South Africa.*
Chimbo Bester *– https://orcid.org/0000-0003-1916-0090; Doctor of Philosophy in Information Systems, Professor, University of South Africa, Johannesburg, South Africa.*
Motsi Lovemore *– https://orcid.org/0000-0002-2149-7429; Doctor of Philosophy in Information Systems, Professor, University of South Africa, Johannesburg, South Africa.*

Introduction

Adherence to medicines is the extent to which the patient's action matches the agreed recommendations by the healthcare provider. According to Franklin et al. (2020), non-adherence to medications can lead to hospitalizations and readmissions, increase mortality rates and adversely affect patients' quality of life. Non-adherence, both intentional and unintentional, limits medication benefits, resulting in health decline and high economic costs attributed not only to wasted medicine but also to knock-on costs arising from increased healthcare demands should health deteriorate (Lin et al., 2022). There are various reasons for patients having difficulty taking their medication. These include constant refills, the perception that medical treatments are improving, forgetfulness, or disinterest in taking medications, and non-availability of medication (Istepanian & Al-Anzi, 2018). Psychologically, patients experiencing comorbid illnesses who take regular medicine are more likely to neglect their medication due either to fatigue or stigmatization or both. It is essential that effort be made to improve patients' adherence to their medications. Such efforts should include support from both healthcare providers and relatives, social support from peers, leveraging of technological innovations, and digital products (Pypenko, 2019) where possible.

Globally, diabetes has been listed among the leading causes of death, with 1.5 million people in 2019 alone dying from this condition (Lin et al., 2022). According to the WHO (2023), in sub-Saharan Africa, South Africa has the second-largest population in this region of people with diabetes (12.7% of adults); and South Africa had 16.0% of the total deaths in 2016 attributed to diabetes and other non-communicable diseases (NCDs). The WHO (2023) emphasizes that diabetes pervasiveness is mainly attributed to lack of awareness of the disease, poor accessibility to proper healthcare, as well as poor adherence to medical prescriptions. Debon et al. (2019) allude to medical-taking inconsistencies have been the major cause of high mortality rates for people with chronic diseases. The above researchers note that routine and timeous taking of medication suppresses the symptoms and other ailments that could complicate diabetic conditions. Hence, failure to take medication regularly allows ailments and symptoms the opportunity to worsen the patient's condition, resulting from low levels of immunity.

Chronic diseases, which are persistent human health conditions, or diseases with long-lasting effects, contribute to various causes of death and disability worldwide (Debon et al., 2019). In both developing and developed countries, chronic diseases have a high prevalence; and are pervasive across all socio-economic classes (Lin et al., 2022; WHO, 2023). Chronic conditions require regular medication administration. The strain of living with conditions that cannot be cured normally leads to distress and depression among patients as a result of taking routine medicines. Such anxiety and depression in patients being aware of living with an incurable malignancy leads to psychological distress, making drug regimen adherence a challenge (Kalema & Mosoma, 2019; Köhler et al., 2017). Diabetic patients need reminders to take care of their health by adhering to the prescribed medicine. This call has led to the development of various self-management reminder systems in which many have leveraged mobile health (mHealth) applications (Reidy et al., 2020).

Debon et al. (2019) note that many of the mHealth systems that have been developed to assist in healthcare monitoring of patients, lack the aspects that could trigger self-monitoring. These researchers indicate that the use of mHealth in the self-monitoring of diabetic patients should be coupled with persuasive technology that embraces both technology and behaviour change; as well as taking into consideration any aspects of cultural context. This paper reports on the development of a persuasive technology mHealth self-monitoring system to enhance adherence to medication among patients with diabetic conditions.

The prevalence of diabetes around the world poses a considerable burden on healthcare systems and patients suffering from this chronic condition. The rise in diabetes and other chronic diseases poses a particular challenge to low-income countries, many citizens lacking adequate medical equipment and clinics (Chang et al., 2022). As a result, nations, as well as healthcare providers, must ensure that four basic functions are provided to the citizens in order to ensure diversity and equality. Among these functions are financial management, provision of stewardship and development of resources, such as human resources, physical infrastructure, and knowledge dissemination (Bacelar-Silva et al., 2022). Additionally, Kendzerska et al. (2021) argue that enabling the effectiveness of these functions will improve the accessibility and responsiveness of the healthcare system. Regardless of the economic standing of a country, healthcare responsiveness is of paramount importance. Some researchers (Pypenko & Melnyk, 2021) argue that building the state economy on the principles of digitalisation will help solve these problems. According to Rensburg (2021), countries should find better ways of ensuring that health systems are equally accessible and available to all citizens, regardless of their geographical location. As part of this process, it is also necessary to bring healthcare closer to communities, especially in areas that are difficult for health workers to reach.

According to Achoki et al. (2022), improving accessibility to healthcare systems is one way of closing the gap between urban and rural settings with limited resources. A number of initiatives have been motivated by attempts to improve the accessibility and availability of healthcare systems. Utilization of technological innovations such as electronic health (e-health) and mobile health (mHealth) has been at the forefront (Arsenijevic et al., 2020; Shaw et al., 2020).

The proliferation of ICTs and the increasing use of mobile telephony continue to be leveraged as mediums of communication between healthcare providers and patients. Consequently, mobile devices such as cellphones, PDAs, and other wireless devices have evolved into patient-monitoring devices. The rapid evolution of mobile technology platforms makes mHealth the fastest-growing segment of eHealth (Shaw et al., 2020). mHealth has played a major role in empowering patients with information, increasing access to health services, and improving real-time data management (Debon et al., 2019). Diabetic patients require continuous monitoring; yet specialists in this domain are few, and those available are overwhelmed by work. Hence remote health-monitoring emerges as a better alternative, preventing unnecessary complications (Istepanian & Al-Anzi, 2018). As a result, mHealth has become a popular tool for monitoring of patients with chronic conditions. Consequently, Chatterjee (2019) has emphasized that, for effective empowerment of patients with chronic conditions, it is essential to leverage persuasive technology that combines the use of technology with the patient's behaviour in responding to drug adherence.

With the advent of digital health technologies, healthcare has undergone a revolution, from the widespread use of computers to algorithms for the detection, treatment, and monitoring of diseases. The use of technology has been extended from robotic surgery to artificial intelligence, machine learning, computer-aided decision models, to mobile applications that help patients to manage their lives (Kgasi et al., 2023). From diseases to electronic medical records, digital health has experienced a revolution. As healthcare systems become more people-centred, the contribution of digital health technologies to preventive and diagnostic treatment, and self-monitoring capabilities becomes enormous. However, many technological interventions in healthcare have been more intended to facilitate the work of healthcare personnel than to facilitate patients managing their lives (Chatterjee, 2019). Researchers such as (Chatterjee, 2019; Debon et al., 2019; Kalema & Mosoma, 2019) argue that, in order to empower patients to self-monitor their health, technological interventions must be designed to incorporate motivational factors that are essential to trigger behaviour change. Earlier researchers such as (Fogg, 2002; Nass et al., 1996) recommended that self-monitoring can be effectively achieved by leveraging persuasive technology.

Fogg (2020) notes that persuasive technology involves the incorporation of psychological insights into the design of products such as mobile apps and wearables, to modify people's habits and beliefs. Therefore, Fogg (2020) believes that the designing process of persuasive technology should consider factors such as ability and motivation, where motivation arises from one's yearning for social connection. This implies that such an individual must have the ability easily to do what the app wants conducted. Therefore, the use of persuasive technology approaches have been widely designed with prompting features, such as reminder systems (Arsenijevic et al., 2020; Huzooree et al., 2019). Fogg (2002) indicated that human beings may respond to computers as though they were living beings. This is mainly because social responses to certain computing systems are automatic and natural. The researcher notes that individuals are hardwired to respond to signals in the environment that seem alive in some way; and such responses are instinctive rather than rational. Additionally, computers can serve as persuasive social actors capable of rewarding individuals with positive feedback, modelling, and providing social support (Nass et al., 1996). When human beings perceive a social presence, they naturally respond in social ways that may include feeling empathy, being angry, or performing a social task (Fogg, 2020). This implies that social cues from computing products are essential. Such social cues trigger automatic responses in individuals whereby a given behaviour happens when motivation, ability, and a prompt come together simultaneously.

Chatterjee (2019) avers that, since human beings respond socially to computer products, the use of persuasive technology is of paramount importance for mHealth self-monitoring of patients with chronic diseases. In mHealth self-monitoring, the mobile device plays the role of persuasion dynamics described as social influence arising from social situations. Researchers such as (Fogg, 2002; Nass et al., 1996) observe that affiliation and social identity effects in human-computer interactions make human beings teaming up with computers behave similarly as they would on teams with other humans in terms of the physical, psychological, social dynamics, social roles, and language. In self-monitoring of diabetes patients, the changes in lifestyle with the use of mHealth is noteworthy in that the mobile apps facilitate the sending of simple messages and alerts aiding in adherence to treatment (Debon et al., 2019). More so, the possibility of providing direct communication by a multimodal content mHealth tool is crucial for higher adherence among patients to routine medicine taking (Arsenijevic et al., 2020).

A literature search was conducted using Litmaps by combining phrases and a combination of the words "mHealth", "mHealth self-monitoring systems", "mHealth self-monitoring systems for diabetic patients", and "mHealth self-management of chronic diseases". The search was filtered to include electronic databases for published articles and conference proceedings, online databases for theses, as well as reference lists of relevant reports and reviews for the years ranging from 2016 to 2023. The search revealed that Dobson et al.'s (2017) study on mHealth for self-management support was the most relevant; and has a wide impact on mHealth self-management research, hence it was used as the seed article. The Dobson et al. (2017) study investigated the use of mHealth in delivering self-management support to young people with Type 1 diabetes. The Dobson et al. (2017) study analysed clinical trials of using the text-message-based diabetes self-management support system in which the role of age in diabetes self-management was emphasized. Much as their study has been widely used, referenced, and extended, the study only analysed the moderating factors descriptively; and such limited the prediction of patients' continuing usage of the intervening mHealth system.

In a systematic review and meta-analysis of mHealth and online health interventions for diabetes published before 2015, Larbi et al. (2019) identified and categorized several factors that influence the use of mHealth for diabetes self-monitoring. These factors included usability and suitability of the developed mobile apps and other online interventions, effect on clinical health measures, data protection, information needs, other external factors, support and access to services, coping, patient engagement and empowerment needs, and technological needs. Their study emphasized that in developing interventions for diabetes self-monitoring, the role that patients and their healthcare professionals play is significant in the development of tools and applications for such chronic diseases self-monitoring. To address this call, our current study developed its artefact based on the Kgasi et al. (2023) model that was quantitatively designed and validated for mHealth self-monitoring.

Reidy et al. (2020) based their study on the behaviour-change wheel and theoretical domains framework in investigating the effects of a facilitated web-based self-management tool for Type 1 diabetic patients using an insulin pump. The study by the above researchers leveraged the combination of contextualization of the healthcare intervention model, use of theory-driven intervention for healthcare self-monitoring, and the use of big sample size of participating patients in the application of the mHealth system. Findings of Reidy et al. (2020) indicated that successful self-management systems are situational and contextual, with time and life circumstances being major moderating factors. Much as their study bridged the gaps that had been presented by earlier researchers such as (Dobson et al., 2017; Larbi et al., 2019), the study fell short of addressing the psychosocial support factors, or their integration into the development of the intervention self-management models and systems.

The integration of psychosocial support into routine diabetes care has been cited as important in reducing challenges of distress, anxiety, depression, and sleep disorders, which are major antecedents of medicine adherence (Kgasi et al., 2023).

The World Health Organization (WHO) report on the uses of self-care interventions indicates that the classification of self-care interventions depends on the purpose of the intervention being developed (World Health Organization, 2021). The report indicates that these classifications include individual agencies that are advanced to promote awareness about self-care. Health information-seeking is recognized, with agencies intended to provide education for informed health decision-making, and social and community support. Such agencies are purposely developed for peer mentorship and counselling and personal health tracking designed to keeping home-based records of health and diagnostic data. Other purposes are self-diagnosis of health conditions intended for self-testing as well as self-management of health. One such developed by this study supports a patient to carry out self-medication and treatment as well as reminding them to take their medicine as prescribed by medical personnel. Other researchers such as (Mueller et al., 2019) stress that, much as various self-management interventions have been developed, including individuals' links to health systems where patients share data with healthcare professionals (HCP), many such systems may be misleading due to poor development procedures. These studies recommended that developed interventions should be scientifically evaluated. The developed intervention system should be feasible, acceptable, usable, efficient, effective, including cost-effective while promoting safety in its implementation.

Lin et al. (2022), using a descriptive analysis approach evaluated Type 1 diabetes patients' accessibility and openness to receiving mHealth support. Their study observed that patients' perceptions of using mHealth as a tool for delivering information is dependent on the delivery style, nature of messages delivered, and the content that is delivered. Hence, the above researchers recommended the implementation of interactive voice response rather than SMS for the elderly chronic-disease patients. Additionally, their study emphasized the importance of leveraging a contextualized model in the development of mHealth interventions: an approach suitable for one population may not be appropriate for another. The current study leveraged the Kgasi et al. (2023) contextualized model in developing the persuasive technology intervention for mHealth self-monitoring.

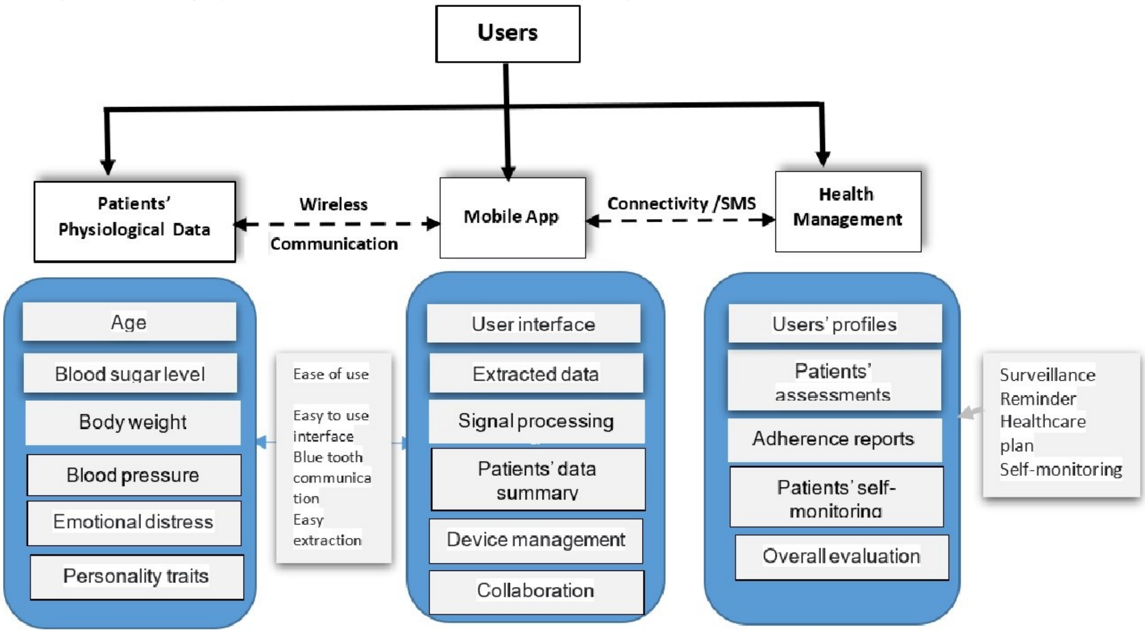
The aim of the study. To implement an intervention mHealth system by integrating persuasive technologies into mobile applications to empower diabetic patients to adhere to medical prescriptions.

Materials and Methods

Researchers Lagan et al. (2021) argue that the proliferation of mobile health apps has made selecting the right one increasingly challenging for clinicians and patients. Despite the myriad of mobile health apps available, app evaluation frameworks can assist in sorting through them; however, the growing number of frameworks further complicates the process. With this understanding, this study set to develop a persuasive mHealth system based on previously validated models (Fogg, 2002; 2009; Kgasi et al., 2023). In persuasive technology, behavioural occurrence is seen as the goal achieved after aggregating other parameters that include motivation, ability, and a prompt (Fogg, 2002). Hence, the general architecture consists of devices connecting the patients' physiological information, implanted systems for signal processing, and wireless communication as demonstrated in Figure 1.

As illustrated in Figure 1, the patients' physiological data and the mobile application components interact directly and are supported by the ease-of-use design principles. Similarly, the persuasive technology characteristics such as assessment, self-monitoring, patients' adherence, as well as evaluation form the components of the health-management system.

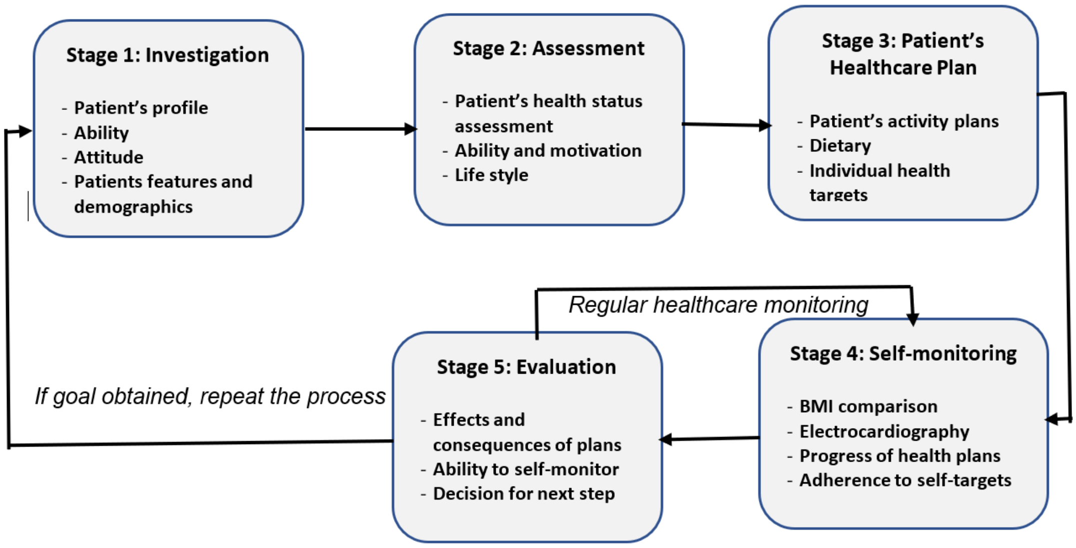
Figure 1
MHealth Self-Monitoring System Architecture (Source: Modified from Jia et al., 2015)



System Functionalities and Integration with Persuasive Technology

The mHealth self-monitoring system functionalities that describe how well it should operate were identified to include productivity, access to information, training, access to diabetes national programmes, security, trust, and scalability (Lagan et al., 2021). On the other hand, for self-monitoring of the system's features, descriptions, dependencies, and functions needed to include registration, patient verification, and push notification, connection to social accounts, utility, news feed, product and services, contacts, messages, dashboard, reports, as well as home screen. The design process considered these functionalities along with Fogg's (2009) five persuasive strategies, namely, investigation, assessment, patient's health plan, self-monitoring, and evaluation. These features were incorporated into the system to enhance patients' execution ability and adherence. Based on these parameters, the design process then followed an iterative approach incorporating patients' feedback and medical personnel evaluation of how the patients have behaved towards the system's triggers as demonstrated in Figure 2.

Figure 2
Integration of Persuasive Technology for Self-Monitoring (Modified from Fogg, 2009; Jia et al., 2015)



Physical Design and Coding of the System

The designed mHealth self-monitoring system is an android application designed with Kotlin programming using the Android Studio working integrated development environment (IDE). Kotlin programming language ensures code safety and developer's satisfaction for professional android developers. The following tools were used:

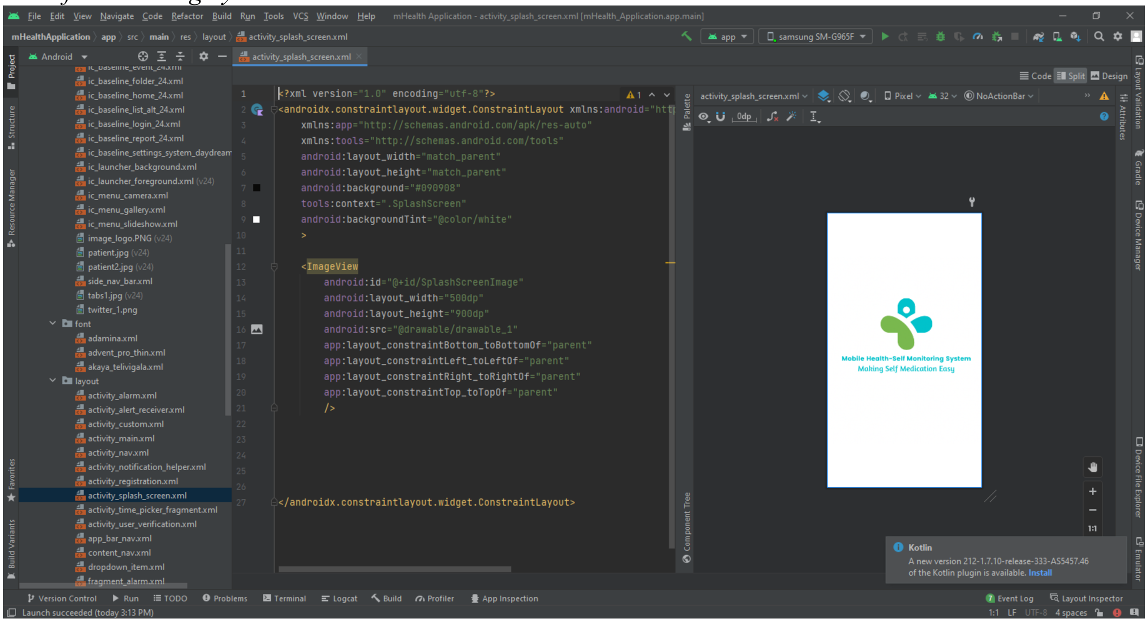
- Firebase real time database, a cloud (online) NoSQL database, that stores and syncs data between users in realtime. This helped to store information about the registered patients on the mHealth system.
- Android Studio an integrated working environment (IDE) designed specifically for android development. This helped in the utilization of the android studio chipmunk that allows the inspection and debugging of the animations features built in a composable preview.
- Android Mobile Phone was used to run the application.

Coding and Graphical Interfaces

The developed frontend and backend were deployed on the android phone to enable the displaying of the output on the graphical interface. A sample of coding of the frontend is demonstrated in Figure 3. Each functionality was developed with both the frontend and backend. The frontend illustrated the patient's interface of interaction with the system; while the backend illustrates the exact occurrence within the system when a function or command is issued.

Figure 3

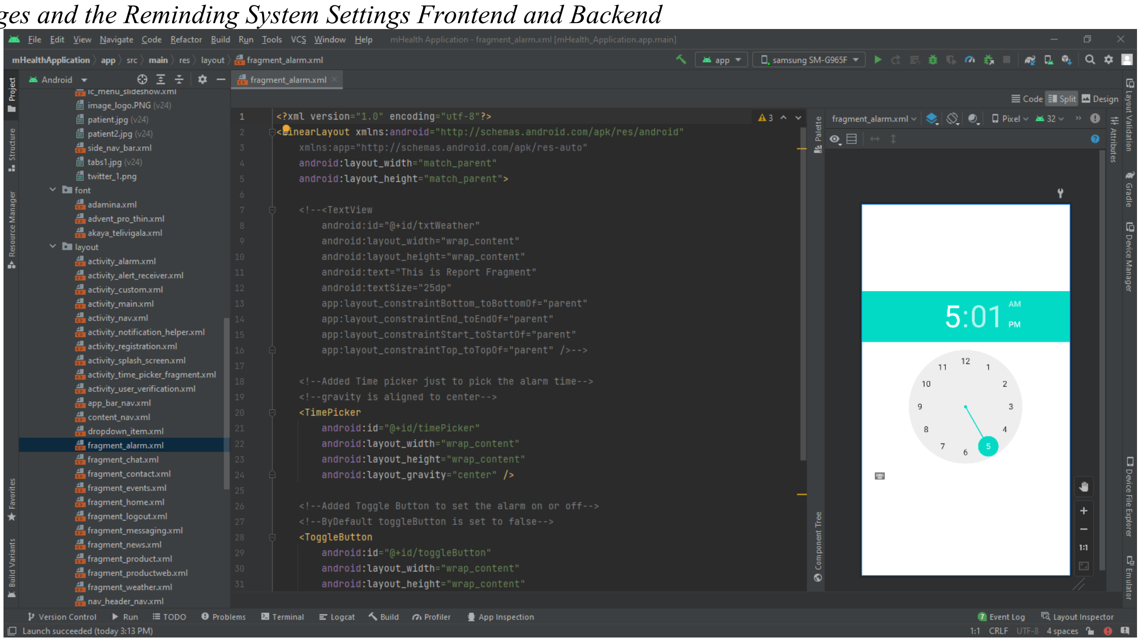
MHealth Self-Monitoring System's Frontend



Since the objective of the mHealth self-monitoring system is to remind a patient to adhere to the medical prescription at the time recommended by the medical personnel or social worker, the system was designed in such way that it takes two approaches to reminding the patient. It first sends a message to alert the patient at the exact time set for medicine-taking; then an alarm automatically goes on. Figures 4 illustrates the messages and the reminding frontend and backend coding. The system also enables a patient to schedule and create personal alarm notifications on the App by setting the ring notification time.

Figure 4

Messages and the Reminding System Settings Frontend and Backend



While on the system, the patient may navigate to perform other tasks such as reading the latest news, setting appointments, browsing the nearest pharmacy, as well as viewing his or her individual report in responding to the system. The "Exit App" button helps the patients to exit the application and resets the system to the "Get Started" page of the App. Additionally, the system was designed in such a way that it allows medical personnel at the facility where the patient is registered to view and produce a report of the patient's performance. Based on these reports, an evaluation of the patient's adherence to the system's triggers, and responses to drug adherence, are recorded including the frequency of the patient's interaction with the system. Adherence is then confirmed by observing the patient's replenishing of the required medicine on time.

Evaluation of MHealth Self-monitoring System

Several methods of testing an artefact may be used to confirm its operability. These may include, inter alia functional and structural testing, testing using experimental methods such as those conducted in the field and laboratories, statistical testing including descriptive and inferential methods, as well as analytical and architectural analysis (Hevner, 2007). Data was collected from medical experts by using a close-ended questionnaire and was analysed descriptively. The artefact was evaluated on the attributes of completeness, functionality, accuracy, reliability, consistency, performance, and usability. Because data was to be analysed descriptively, a small sample of about 20 respondents was deemed sufficient. The judgment-sampling technique was used to select the respondents. The experts sought were healthcare professionals, both medical and social workers, with relevant experience of working with diabetic patients. The artefact was deployed on these experts' cellphones and the experts were asked to practise with it for a period of two weeks. The questionnaire was distributed in person; and experts were allowed three days for its completion.

Results

Respondents were asked to evaluate the artefact based on the seven attributes of completeness, functionality, accuracy, reliability, consistency, performance, and usability. Results presented in Table 1 demonstrate the respondents' evaluation of how best the mHealth self-monitoring system design conforms to the expected criteria in terms of the seven tested attributes.

Table 1
Descriptive Analysis of Artefact Evaluation Parameters

Parameters	N Statistic	Min. Statistic	Max. Statistic	Mean Statistic	Std. Dev. Statistic	Variance Statistic	Skewness Statistic	Skewness Std. Error
Completeness	20	2	5	3.75	1.070	1.145	-0.304	0.512
Functionality	20	2	5	4.05	0.945	0.892	-0.524	0.512
Accuracy	20	2	5	3.70	1.031	1.063	-0.282	0.512
Reliability	20	2	5	3.90	0.968	0.937	-0.170	0.512
Consistency	20	3	5	4.00	0.795	0.632	0.000	0.512
Performance	20	2	5	3.75	1.251	1.566	-0.548	0.512
Usability	20	2	5	3.55	0.999	0.997	0.024	0.512
Valid N (listwise)	20	–	–	–	–	–	–	–

Implications of Findings

Completeness: This aspect evaluated whether the artefact's components were sufficiently complete to enable patients and medical personnel to interact with the systems, as well as being in a position to receive and share information. Findings indicate that the minimum and maximum responses are 2 and 5; with a mean of 3.75, and standard deviation of 1.07. This implies that most responses were skewed towards agreeing that the system is complete and could be used for monitoring patients' adherence to medicine.

Functionality: This aspect tested the artefact's usefulness; and how best it reminds the patients to adhere to the medical prescriptions. Functionality was tested in terms of the system's input, processing, storage, as well as the output, including the extracted reports by the medical personnel. Results demonstrated in Table 1 indicate that responses had a minimum of 2 and a maximum of 5, with a mean of 4.05 and a standard deviation of 0.945. The implication of these findings is that experts considered the system to be performing averagely, as expected.

Accuracy: This aspect evaluated the degree of closeness of the artefact to perform self-monitoring. This was in terms of the level of quality and precision, stability and security, and providing solutions without confusion. As demonstrated in Table 1, the minimum and maximum responses were 2 and 5, respectively, with a mean of 3.70 and a standard deviation of 1.031. The findings of the study imply that many respondents were skewed towards agreeing that the artefact accurately gives the expected results.

Reliability: This aspect assessed the probability that the artefact performs correctly regardless of the time and location, and is performing adequately according to predefined specifications and requirements. Results demonstrated in Table 1 indicate that experts' responses were more skewed towards agreeing that the system is reliable, and performs according to stated functional and non-functional requirements. Reliability is essential for event-based reporting that occurs on a daily basis; hence this confirms that the system will perform to expectations.

Consistency: This aspect evaluated the system's capability of producing a solution as intended. In the case of this study, consistency refers to whether the mHealth self-monitoring system could support patients in self-managing their health. Results demonstrated in Table 1 indicate that experts' evaluations were a minimum of 2 and a maximum of 5 with a mean of 3.90 and standard deviation of 0.968. This confirms that accuracy and consistency of mHealth self-monitoring are important in assessing and understanding predictive validity. Such includes the ability to detect events or pattern changes and for the intervention of the application.

Performance: The system was evaluated in terms of how well it does the reminding of the patients; and whether it accurately sends the messages as and when needed. Results demonstrated in Table 1 indicate that the majority of the respondents 70% (n=14) agreed that the system performs to expectations. The implication of this findings is that self-monitoring strategies are essential in helping patients maintain adherence to medical prescription for their own progress toward controlling complications that could be caused by the diabetic conditions.

Usability: As demonstrated in Figure 1, the mHealth self-monitoring system architecture emphasized that the system be developed with ease-of-use features. This implies that both the patients and healthcare workers should be able to navigate and use the system with ease. Results demonstrated in Table 1 indicate that responses were a minimum of 2 and a maximum of 5, with a mean of 3.55 and standard deviation of 0.999, with a positive skewedness of 0.024. Therefore, most responses were towards "agree" and "strongly agree". The implication of this finding is that usability plays a key role in engagement and behaviour changes.

By interacting with the system, a high-usability mHealth self-monitoring system should increase engagement and result in positive behaviour change.

Discussion

This paper presents a designed artefact that can be implemented into a fully-fledged mHealth self-monitoring system to assist diabetic patients to adhere to medical prescriptions. The designed artefact was evaluated by healthcare personnel in terms of its completeness, functionality, accuracy, reliability, consistency, performance, and usability. Results indicated that the artefact meets a good measure of patients' self-monitoring of their health. The evaluation results also suggested that some functionality of the mHealth self-monitoring system requires an incremental improvement, so as to provide a seamless healthcare support. Preventing NCDs is crucial to enabling better healthcare so as reduce long-term care costs while harnessing the potential of economic growth.

It is vital that better disease-management strategies, systems, and innovative tools are implemented to support the already overburdened healthcare systems, especially in low-income countries (Yagiz & Goderis, 2022). In this regard, new tools and integrated care models such as self-monitoring systems are required to support primary, community, and home-based healthcare, as well as long-term care.

Due to experiences of COVID-19 that introduced travel restrictions and social distancing, accessibility to medical facilities was limited; and such emphasized the need for electronic medical care systems. As a result, mHealth self-monitoring systems are regarded as effective tools for fostering physical well-being and quality of life for patients (Chifu et al., 2022; Cruz-Ramos et al., 2022; Prioleau, 2021).

Other technologies could also be used in the same manner; and these include assistive technologies to monitor nutrition and physical activity, awareness campaigns to promote health, and digitally accessible community-based and integrated-care models to improve access to healthcare services.

As the prevalence of diabetes increases worldwide, it places a considerable burden on countries' healthcare systems as well as on the economic conditions of patients suffering from these chronic conditions. Therefore, leveraging technological innovations such as the mHealth self-monitoring system could save diabetic patients from the challenges of resource constraints and give these patients an added advantage of enhanced self-care.

The mHealth self-monitoring system architecture presented in Figure 1 indicated that the system should be developed with ease-of-use features; and should be beneficial to the intended users. These two technological aspects are essential in that, because diabetic conditions are prevalent in both youth and adults, the developed system should be accessible to all age groups. The system should be easy to use and at the same time patients should appreciate its usefulness. As Jia et al. (2015) note, failure to make the mHealth system easy to use will imply usage limited to only younger age patients, leaving the elderly ones socially isolated. Enhancing positive social support network is generally crucial to a patient's well-being, irrespective of chronic diseases complications, as this improves their positive motivation towards adherence, leading to better recovery. Additionally, social support for patients increases resilience to stress, hence lessening effects of trauma and depression (Fogg, 2020; World Health Organization, 2023).

Due to the stigmatization of having incurable health conditions, chronic-disease patients sometimes become reserved when interacting with peers, leading to low self-esteem (Kalema & Mosoma, 2019; Köhler et al., 2017). Hence, healthcare intervention programmes should not be limited to building the capacity of individual patients as well as their family members, in managing the chronic disease effectively. Programmes should also emphasize the use of technological innovations such as the mHealth self-monitoring system. Additionally, individuals with chronic physical illness are at increased risk of negative psychological sequelae; hence self-monitoring systems act as an intermediary innovative approach intended to reduce these negative effects and increase quality of life in such individuals (de Leeuwerk et al., 2022).

The fact that the persuasive mHealth self-monitoring system embraces the integration of patients' behaviour with technology is a good alternative to human medical personnel when dealing with patients with chronic illness. Delivering a smartphone intervention system is feasible as it meets the desired criteria of availability, demand, acceptability, and limited-efficacy testing (Huberty et al., 2019).

Limitations and Recommendations

The use of persuasive technology involves the incorporation of technological aspects of mobile-technology software and hardware, along with the users' individual characteristics and other triggering factors such as environment, institutional support, social, as well as cultural aspects, to cause behaviour change. The development of the artefact was based on the pre-tested model (Kgasi et al., 2023) that had been developed with consideration of patients' demographics and situational variables to moderate behavioural change. However, the evaluation of the artefact was based on the system's parameters, namely, completeness, functionality, accuracy, reliability, consistency, performance, and usability, without considering the evaluators' demographic variables. Furthermore, the evaluation was conducted at one time only, yet system usage behaviour may change over time (Chang et al., 2022; Fogg, 2009; Kalema & Mosoma, 2019). Therefore, this study recommends that future research use longitudinal data collection in which data on the effectiveness of the system is collected at different intervals after usage. This will help to identify those parameters that have ceased to be significant, together with those that have become salient.

The increasing globalization and urbanization is seeing a number of chronic diseases both communicable and non-communicable becoming more prevalent (Huberty et al., 2019; World Health Organization, 2023). As the number of citizens with chronic disease increases, healthcare systems become overwhelmed with the many patients who require routine healthcare. Technological innovations such as mHealth self-monitoring become key players in improving patients' self-management of their health. The mHealth self-monitoring system developed for this study goes beyond simply providing health information and SMSs, to include a reminder system and printing of the patient's reports on interaction with the system. The reminder system was developed in such a way that the time for the alarm to go on and the sending of messages are set manually either by the patient or a healthcare worker. This implies that the system is not intelligent enough to detect from the patient's condition that the alarm or reminder should sound. This study therefore recommends that future research should develop the mHealth self-monitoring that is intelligent enough to automatically detect patient's triggers for reminders before the alarm goes on. Patients' reports on the healthcare personnel's site should be based on real-time responses to allow immediate actions by the medical personnel. Such real-time interventions will help to ease the work of the healthcare personnel due to increasing numbers of patients.

This study was concerned with the development of a self-monitoring system for medicine adherence only, with no intervention for influencing health outcomes. However, there are also various other ways by which diabetic patients may be monitored, such as rate of physical activity, weight gain or loss, and blood-glucose levels. These other health-monitoring facilities were out of the scope of this study. Future research could develop mHealth systems that combine all these health conditions that should be monitored, into one integrated system. Furthermore, due to increasing numbers of patients suffering from chronic conditions, data storage, as well as network stability, may become an impediment for effective use of the mHealth self-monitoring system. This study therefore recommends that future mHealth system and device integration be developed, supported by a more comprehensive, cloud-based system. Cloud-based solutions will provide various benefits, including stability, availability, and security, in addition to healthcare personnel being in a position to analyse patients' data from a central platform.

Conclusions

The pervasiveness of the use of technological innovations into the healthcare domain, and the increase of disease burdens, has made mHealth a much sought-after tool in the healthcare sectors of many countries. mHealth has been widely applied to the various aspects of healthcare management, especially to chronic complications that require routine monitoring, making adherence a challenge (Huberty et al., 2019; Leeuwerk et al., 2022). mHealth systems such as the one developed in this study not only work as a reminder system for patients, but also allow healthcare professionals to collect quantitative information related to patients' health and behaviour towards medicine adherence; and such helps personnel to make meaningful decisions.

Through the data generated, stored, and disseminated by the mHealth systems, healthcare providers will be capable of gathering patients' related data and making decisions such as patients' risk prediction, need for physical monitoring, or admission to intensive care. On the other hand, the integration of patients' electronic health records, their behaviour and wearable technologies through the use of mHealth self-monitoring is essential for patient self-monitoring of their chronic conditions. Hence, an understanding of how to use the data generated from patients suffering from chronic conditions such as diabetes could lead to better treatment. Such could also lead to effective monitoring and control of other related complications that may arise from worsened conditions of chronic diseases due to poor adherence to medicine (Shaw et al., 2020). This is essential especially for diabetes where related complications leads to increased the risk heart problems such as heart attack, stroke and narrowing of arteries that may lead to death.

Acknowledgments

The authors wish to thank all healthcare providers, social workers and administrators who helped in one form or another during the processes of setting up appointments for securing ethical clearance and collection of data, as well as those who participated in the study.

Ethical Approval

The study obtained ethical clearance from the Ethics Committee of University of South Africa, UNISA (No. 2022/CAES_HREC/105 from 6/06/2022).

Funding Source
This research did not receive any outside funding or support.

References

Achoki, T., Sartorius, B., & Watkins, D. (2022). Health trends, inequalities and opportunities in South Africa's provinces, 1990-2019: Findings from the Global Burden of Disease 2019 Study. *Journal of Epidemiol Community Health, 76*(5), 471–481. https://doi.org/10.1136/jech-2021-217480

Arsenijevic, J., Tummers, L., & Bosma, N. (2020). Adherence to electronic health tools among vulnerable groups: Systematic literature review and meta-analysis. *Journal of Medical Internet Research*, *22*(2). https://doi.org/10.2196/11613

Bacelar-Silva, G. M., Cox III, J. F., & Rodrigues, P. P. (2022). Outcomes of managing healthcare services using the Theory of Constraints: A systematic review. *Health Systems*, *11*(1), 1–16. https://doi.org/10.1080/20476965.2020.1813056

Chang, Y. T., Tu, Y. Z., Chiou, H. Y., Lai, K. & Yu, N. C. (2022). Real-world benefits of diabetes management app use and self-monitoring of blood glucose on glycemic control: Retrospective analyses. *Journal of Medical Internet Research*, *Mhealth Uhealth*, *10*(6), https://doi.org/10.2196/31764

Chatterjee, S. (2019). Can "persuasive technology" change behavior and help people better manage chronic diseases? *Medical Xpress.* https://medicalxpress.com/news/2018-10-persuasive-technology-behavior-people-chronic.html

Chifu, V. R., Pop, C. B., Demjen, D., Socaci, R., Todea, D., Antal, M., Cioara, T., Anghel, I., & Antal, C. (2022). Identifying and Monitoring the daily routine of seniors living at home. *Sensors (Basel),* 22(3), Article 992. https://doi.org/10.3390/s22030992

Cruz-Ramos, N. A., Alor-Hernández, G., Colombo-Mendoza, L. O., Sánchez-Cervantes, J. L., Rodríguez-Mazahua, L., & Guarneros-Nolasco, L. R. (2022). mhealth apps for self-management of cardiovascular diseases: A scoping review. *Healthcare*, *10*(322). https://doi.org/10.3390/healthcare10020322

Debon, R., Coleonea, J. D., Bellei, E. A., & De Marchi, A. C. B. (2019). Mobile health applications for chronic diseases: A systematic review of features for lifestyle improvement. *Diabetes & Metabolic Syndrome: Clinical Research & Reviewer, 13*(4), 2507–2512 https://doi.org/10.1016/j.dsx.2019.07.016

de Leeuwerk, M. E., Botjes, M., van Vliet, V., Geleijn, E., de Groot, V., van Wegen, E., van der Schaaf, M., Tuynman, J., Dickhoff, C., & van der Leeden, M. (2022). Self-monitoring of physical activity after hospital discharge in patients who have undergone gastrointestinal or lung cancer surgery: Mixed methods feasibility study. *JMIR Cancer*, *8*(2): e35694. https://doi.org/10.2196/35694

Dobson, R., Whittaker, R., Murphy, R., Khanolkar, M., Miller, S., Naylor, J., & Maddison, R. (2017). The use of mobile health to deliver self-management support to young people with type 1 diabetes: A cross-sectional survey. *JMIR Diabetes*, *2*(1), 1–9, https://doi.org/10.2196/diabetes.7221

Fogg, B. J. (2009). A behavior model for persuasive design. Persuasive '09: *Proceedings of the 4th International Conference on Persuasive Technology,* Article 40. https://doi.org/10.1145/1541948.1541999

Fogg, B. J. (2002). Persuasive technology: Using computers to change what we think and do. *Ubiquity, 2002,* Article 5. https://doi.org/10.1145/764008.763957

Fogg, B. J. (2020). *Tiny habits: The small changes that change everything*. Houghton Mifflin Harcourt. https://st.catalog.lionlibraries.org/Record/.b26221317

Franklin, B. D., Abel, G. & Shojania, K. G. (2020). Medication non-adherence: an overlooked target for quality improvement interventions. *BMJ Quality & Safety*, 29, 271–273, https://doi.org/10.1136/bmjqs-2019-009984

Hevner, A.R. (2007). A three cycle view of design science research. *Scandinavian Journal of Information Systems,* 19(2), 87–92. https://aisel.aisnet.org/sjis/vol19/iss2/4

Huberty, J., Eckert, R., Larkey, L., Kurka, J., Rodríguez, De Jesús, S.A., Yoo, W., & Mesa, R. (2019). Smartphone-based meditation for myeloproliferative neoplasm patients: Feasibility study to inform future trials. *JMIR Formative Research*, *3*(2): e12662, https://doi.org/10.2196/preprints.12662

Huzooree, G., Khedo, K. K., & Joonas, N. (2019). Pervasive mobile healthcare systems for chronic disease monitoring. *Health Informatics Journal*, *25*(2), 267–291, https://doi.org/10.1177/1460458217704250

Istepanian, R. S., & Al-Anzi, T. M. (2018). m-Health interventions for diabetes remote monitoring and self-management clinical and compliance issues. *mHealth*, *4*, Article 4. https://doi.org/10.21037/mhealth.2018.01.02

Jia, G., Yang, P., Zhou, J., Zhang, H., Lin, C., Chen, J., Cai, G., Yan, & Ning, G. A. (2015). A framework design for the mHealth system for self-management promotion. *Bio-Medical Materials and Engineering*, *26*(S1), S1731–1740. https://doi.org/10.3233/BME-151473

Kalema, B., M., & Mosoma, R.M. (2019). Mobile Health monitoring systems model for chronic diseases patients in developing countries. *2019 IEEE 10th Annual Information Technology, Electronics and Mobile Communication Conference (IEMCON),* Vancouver, BC, Canada, 2019, (pp. 0820–0826). https://doi.org/10.1109/IEMCON.2019.8936181

Kendzerska, T., Zhu, D. T., Gershon, A. S, Edwards, J. D., Peixoto, C., Robillard, R., & Kendall, C. E. (2021). The effects of the health system response to the COVID-19 pandemic on chronic disease management: A narrative review. *Risk Management and Healthcare Policy, 14*, 575–668. https://doi.org/10.2147/RMHP.S293471

Kgasi, M., Chimbo, B., & Motsi, L. (2023). mHealth self-monitoring model for medicine adherence of diabetic patients in developing countries: A structural equation modelling approach. *JMIR Formative Research, 7,* Article e49407. https://doi.org/10.2196/49407

Köhler, N., Mehnert, A., & Götze, H. (2017). Psychological distress, chronic conditions and quality of life in elderly hematologic cancer patients: Study protocol of a prospective study. *BMC Cancer*, *17*, Article 700. https://doi.org/10.1186/s12885-017-3662-1

Lagan, S., Sandler, L., & Torous, J. (2021). Evaluating evaluation frameworks: A scoping review of frameworks for assessing health apps. *BMJ Open*, *11*(3), Article e047001. https://doi.org/10.1136/bmjopen-2020-047001

Larbi, D., Bradway, M., Randine, P., Antypas, K., Gabarron, E., & Arsand, E. (2019). Do diabetes mHealth and online interventions evaluate what is important for users? *Linköping Electronic Conference Proceedings, 161,* 30–36. https://hdl.handle.net/11250/2828921

Lin, Y., K., Richardson, C., Dobrin. I., Pop-Busui, R., Piatt, G., & Piette, J. (2022). Accessibility and openness to diabetes management support with mobile phones: Survey study of people with type 1 diabetes using advanced diabetes technologies. *JMIR Diabetes*, *7*(2), Article e36140. https://doi.org/10.2196/36140

Mueller, S. M., Jungo, P., Cajacob, L., Schwegler, S., Itin, P., & Brandt, O. (2019). The absence of evidence is evidence of non-sense: Cross-sectional study on the quality of psoriasis-related videos on YouTube and their reception by health seekers. *Journal of medical Internet research*, *21*(1), Article e11935. https://doi.org/10.2196/11935

Nass, C. I., Fogg, B. J., & Moon, Y. (1996). Can computers be teammates? Affiliation and social identity effects in human-computer interaction. *International Journal of Human-Computer Studies*, *45*(6), 669–678. https://doi.org/10.1006/ijhc.1996.0073

Prioleau, T. (2021). Learning from the experiences of COVID-19 survivors: Web-based survey study. *JMIR Formative Research, 5*(5), Article e23009, https://doi.org/10.2196/23009

Pypenko, I. S. (2019). Digital product: The essence of the concept and scopes. *International Journal of Education and Science, 2*(4), 56. https://doi.org/10.26697/ijes.2019.4.41

Pypenko, I. S., & Melnyk, Yu. B. (2021). Principles of digitalisation of the state economy. *International Journal of Education and Science, 4*(1), 42–50. https://doi.org/10.26697/ijes.2021.1.5

Reidy, C., Foster, C., & Rogers, A. (2020). A facilitated web-based self-management tool for people with type 1 diabetes using an insulin pump: Intervention development using the behavioural change wheel and theoretical domains framework. *Journal of Medical Internet Research*, *22*(7), Article e21381. https://doi.org/10.2196/21381

Rensburg, R. (2021). *Healthcare in South Africa: How inequity is contributing to inefficiency.* The Conversation. https://theconversation.com/healthcare-in-south-africa-how-inequity-is-contributing-to-inefficiency-163753

Shaw, R.J., Yang, Q., Barnes, A., Hatch, D., Crowley, M. J., Vorderstrasse, A., Vaughn, J., Diane, A., Lewinski, A. A., Jiang, M., Stevenson, J., & Steinberg, D. (2020). Self-monitoring diabetes with multiple mobile health devices. *Journal of the American Medical Informatics Association, 27*(5), 667–676. https://doi.org/10.1093/jamia/ocaa007

World Health Organisation. (2021). *Classification of self-care interventions for health: A shared language to describe the uses of self-care interventions.* https://iris.who.int/bitstream/handle/10665/350480/9789240039469-eng.pdf?sequence=1

World Health Organization. (2023, April 5). *Diabetes.* https://www.who.int/news-room/fact-sheets/detail/diabetes

Yagiz, J. I., & Goderis, G. (2022). The impact of the COVID-19 pandemic on eHealth use in the daily practice and life of Dutch-speaking, General Practitioners in Belgium: Qualitative Study With Semi structured Interviews *JMIR Formative Research*, *6*(11), Article e41847. https://doi.org/10.2196/41847

Cite this article as:
Kgasi, M. R., Chimbo, B., & Motsi, L. (2024). A persuasive technology mhealth self-monitoring system for intervention in diabetic patients medical adherence. *International Journal of Science Annals, 7*(2), 1–11. https://doi.org/10.26697/ijsa.2024.2.2

The electronic version of this article is complete. It can be found online in the IJSA Archive https://ijsa.culturehealth.org/en/arhiv