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Journal of Health Informatics in Africa

Editorial to JHIA Vol. 11 (2024) Issue 2

Nicky Mostert

Nelson Mandela University, Port Elizabeth, South Africa

The Journal of Health Informatics in Africa (JHIA) only publishes original, high quality research papers focusing on the use of information and ICTs in the healthcare sector in Africa.

To ensure originality a Turnitin report is obtained for each submission before being assigned to reviewers. Only submissions with a Turnitin similarity index below 15% are accepted for review. Submission with a higher similarity index is immediately rejected. Authors are thus urged to ensure that their submissions are original and that it has not been published elsewhere before submission is made to JHIA. Once a submission is accepted for review it passes through a rigorous double-blind review process that either results in a rejection or acceptance. Most submissions that are accepted are subject to a second round of review. Authors are tasked to revise the paper based on the reviewer feedback and re-submit it for a second round of review by the same reviewers. Only once the reviewers and editorial team are satisfied with the revisions are the paper then formally accepted for publication.

To attest to the rigorous review process this issue comprises of only two papers:

- Gumede and Dyers presents a cross-sectional evaluation of the user experience of an Electronic Medical Record (EMR) in the public health sector of the Western Cape in South Africa. The user experience of the EMR is evaluated in terms of it's pragmatic- and hedonic qualities.
- Mutunhu, Chipangura, and Singh explores opportunities for quantified-self technology in diabetes self-care through a systematic literature review. Four opportunities namely monitoring, adherence, reduced cost, and data collection and sharing are identified.

I would like to extend a very special thank you to the editorial team, authors, and peer-reviewers that made this issue possible. I encourage readers active in health informatics research to make contact with me to become reviewers for JHIA. We rely on the expertise of experienced researchers to ensure the publication of high-quality research.

Nicky Mostert
July 2024

Journal of Health Informatics in Africa

User Experience of an Electronic Medical Record: A Cross-Sectional Study in the Public Health Sector of the Western Cape, South Africa

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Background and Purpose: The Electronic Continuity of Care Record (eCCR) is a web-based Electronic Medical Record commissioned and implemented by the Western Cape Government Health and Wellness department in 2015 for all 53 public hospitals in the province to capture medical records of patients. While there has been previous research into the quality of clinical coding capture within the eCCR, there has not yet been a formal evaluation of end users' experience (UX) of the application. This study is the first formally to evaluate the user experience of an eHealth application in the public sector in the Western Cape.

This study which evaluated the user experience of the eCCR end users in terms of its *attractiveness*, pragmatic qualities (*efficiency*, *perspicuity*, *dependability*) and hedonic qualities (*stimulation*, *novelty*), describes the characteristics of end users and explores associations between user characteristics and the UX of eCCR.

Methods: A validated UX Questionnaire survey was made available online to evaluate the eCCR user experience. An invitation and link to the survey was added on the eCCR landing webpage specifically to target users of the application. Response data were collected over three months from June to August 2023 using 26 UEQ questions that comprised Lickert-type scales of 1-7 to rate experience. The mean was determined for each scale. Mean scale values > 0,80 represented a positive experience. Values between -0.80 and 0.80 represented neutral experience while values < -0,80 represented a negative experience.

Results: There were 201 participants in this study. The question (item) response means were combined per scale: attractiveness=0.87, perspicuity=1.32, dependability=0.88, stimulation=0.76, efficiency and novelty reported low means of 0.55 and 0.30 respectively.

Conclusion: The User Experience UX evaluation indicated that the eCCR was an easy-to-learn and understandable web-based application, the end users reported it was valuable, secure, enjoyable, and met user expectations. The overall *attractiveness* of application was positive. The pragmatic qualities of the eCCR were rated higher than the hedonic qualities. The study indicated that the eCCR can be strengthened with regard to its innovative and creative features to improve upon the experience scales related to *novelty,* as well as its *efficiency*.

Keywords: user experience, electronic medical record, public health

1 Introduction

User Experience (UX) was defined by International Organisation for Standards, as "users' perceptions and responses that result from the use and/or anticipated use of a system, product, or service. Users' perceptions and responses include the users' emotions, beliefs, preferences, perceptions, comfort, behaviours, and accomplishments that occur before, during and after use. UX is a consequence of brand image, presentation, functionality, system performance, interactive behaviour, and assistive capabilities of a system, product, or service. It also results from the user's internal and physical state resulting from prior experiences, attitudes, skills, abilities and personality; and from the context of use [1][2]."

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The World Health Organization developed a global strategy on digital health with the purpose of increasing access to information and communications technology in least developed countries [3]. While the strategy does not explicitly mention “user experience” it does, however, propose the following as a policy option and action: “ensure that institutions, decision-makers and personnel involved in the provision of health care services and all end-user communities and beneficiary populations are adequately engaged in the design and development phases [3].”

Taking UX into consideration is key to delivering products that meet the users’ needs and are easy to use or understand with the aim of giving users a positive experience [4][5]. Research in UX can help improve the design of healthcare technology and end user satisfaction, while enhancing the wellbeing of staff [4][6]. It is also useful in planning new developments on health technology software and applications. Literature in UX has demonstrated that engaging users at development stages of the Electronic Medical Records (EMR) improves the adoption of the applications [7][8][9].

An EMR is the digital equivalent of paper patient records or charts [10]. It typically contains information such as medical history, investigation results, treatment and plans for continuity of care of a patient as it is collected by the health service provider [10]. The EMR enhances and supports continuity of care, access to quality care, patient safety and health care productivity while indirectly enabling a better experience of the health service by patients [7][11][12].

The user experience questionnaire (UEQ) was developed by Martin Schrepp in 2005 [13]. There have since been several translations and validations of the tool [13][14]. The use of the UEQ to evaluate EMR systems in health has successfully been used in developed country settings [7,11]. In Canada, researchers conducted a UX survey in six public hospitals to explore the experiences and perceptions of healthcare providers using the existing EMRs. The participants reported that they experienced positive outcomes, quality patient care and improved productivity. They also observed that the longer end users use an EMR system the more the adoption and user experience improve [11].

Laugwitz et al, reported the UEQ in its standard form appears to be an easy to apply, reliable and valid measure for user experience that can be used to complement data from other evaluation methods with subjective quality ratings [14]. However, some limitations include that the items on questionnaires cannot be changed or removed, as this will influence the results.

A South African UX study conducted in 2014 reported that end users interacting with government websites often found that they did not meet their user needs [15]. The 2019-2024 National Digital Strategy for South Africa states that user experience of systems is a critical factor in the systems’ success [16]. Additionally, the National Development Plan has a vision for a single cohesive digital strategy where existing information systems for patient care will be centrally coordinated at national and provincial levels [3][16].

Though the use of EMRs has increased over the years in both developed and developing countries, in Africa there is limited literature on UX of EMRs. Most of the literature on EMRs in the Sub-Saharan Africa focuses on the factors that hinder implementation [17][18]. A study conducted in Khayelitsha Hospital in the Western Cape reported that the failures of current EMRs are leading to ineffective capturing of patients’ information. It also highlighted the need for a national comprehensive EMR [19].

A systematic review assessing usability on the implemented EMR systems in Africa reported that less attention was given to user satisfaction during implementation, and this impacted the usability of EMR systems [20]. Hassenzahl stated that there tends to be greater emphasis on usability and utility of applications than giving end users a rich user experience [5]. Furthermore, they recommended designers and developers should consider the gathering and analysis of hedonic requirements in addition to usability and functional requirements [5].

The Western Cape Government Health and Wellness (WCGHW) department developed a web-based application called the Electronic Continuity of Care Record (eCCR) to improve the UX of the digital aspects of the patient discharge process as part of its Strategic Information and Communications Technology Plan for Health [21]. The eCCR is used by clinicians, nurses, allied health workers and clerical staff in all public hospitals in the Western Cape Province to integrate and improve discharge processes for in-patients, referrals for outpatients, electronic prescriptions, clinical concept coding, procedure lists, the generation of medical certificates, and ultimately to improve continuity of care. At the time of this research, the eCCR had approximately 900 active users. Since the launch of eCCR in 2015 there has been previous research into the quality of International Classification of Disease (ICD) code data but there has not yet been a formal

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evaluation of end users' experience of the application [22][23]. This study is the first formally to assess the UX of the eCCR or any eHealth system in the Western Cape public health sector.

This study being the first UX research for this application, it is anticipated that the results will contribute to future developments or improve the current UX of the eCCR. The UX research can be used to understand user needs in order to deliver informed, relevant and innovative design solutions, that meet users' needs [24]. The study assessed the experiences of eCCR end users in the Western Cape public sector hospitals in terms of overall attractiveness, pragmatic, and hedonic qualities of the eCCR application. Furthermore, it explored the association between the number of months end-users used the application and their user experience.

2 Materials and Methods

The study method comprised a cross-sectional survey method in the form of an electronic self-administered validated UX questionnaire [25]. The study was conducted over a three-month period from June to August 2023.

2.1 Study Criteria

The study participants included eCCR end users in Western Cape public hospitals. Users included clinicians, allied health workers, nursing staff and administration staff. The study targeted end users with more than one month's experience of using the eCCR to participate in this survey. Users with read-only access and inactivity of more than 60 days were excluded from the study.

2.2 Sample Size

At the time the study was conducted there were approximately 900 active users of the eCCR. A standard value of population proportion of 50%, 95% confidence level, and a margin of error of 5% was used to estimate the required *n* of 270 participants, due to the global tendency of low response rates to survey invitations [26].

2.3 Recruitment Strategy

A hyperlink to invite eCCR users to participate in the UX survey was added to a splash screen when users logged into the application. Printed Quick Response (QR) codes were posted in hospital wards to encourage participation in the survey. The questionnaire was structured to exclude and automatically exit users that did not meet the study inclusion criteria.

2.4 Data Collection Instrument

This study used a standardized UEQ long questionnaire by Martin Schrepp et al [13]. The questionnaire included 26 questions where the participants had to rate their experience on a scale 1-7. Each question could be ascribed to broader scale categories (Fig. 1).

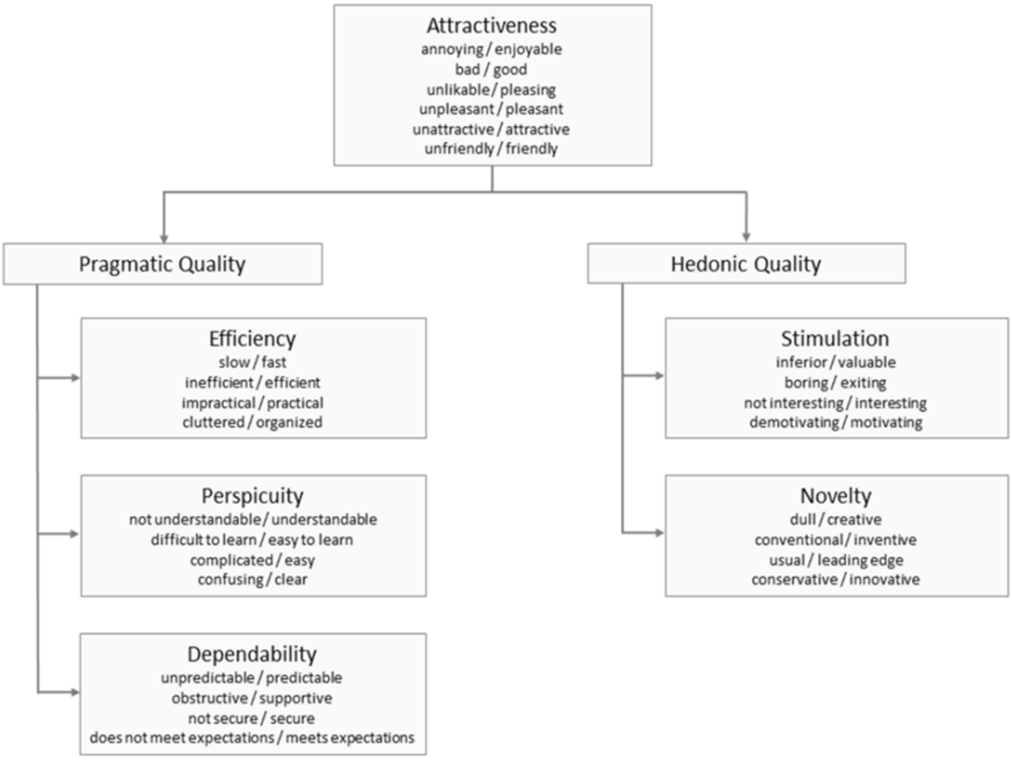

Figure 1. User Experience Questionnaire scale structure (Source: UEQ Handbook, 2008)

Figure 1 elaborates on the meaning of each score. The response scores were grouped according to *pragmatic* and *hedonic* qualities, where pragmatic quality described task related quality aspects, hedonic quality, and the non-task related quality aspects such as originality and innovativeness. *Attractiveness* referred to users' overall impression of the product while efficiency measured whether users could solve their tasks without unnecessary effort. *Perspicuity* measured how easy it was to become familiar with the product. *Dependability* measured whether users felt in control of the interaction. *Stimulation* measured how exciting and motivating it was to use the product. *Novelty* measured whether the product was creative [13][20].

The questions or items had two terms with opposite meanings to describe the user's experience. The questions were randomly organized. Half of the questions started with the positive term and the other half started with the negative term. These were then shuffled to reduce a tendency towards either end of the scale. The UEQ used a seven-point scale to reduce the well-known central tendency bias for these type of questions [14].

2.5 Data Collection

Data were collected using a self-administered electronic questionnaire developed in Microsoft Forms™. This was accessible online via a link on the eCCR website or by scanning a QR code posted in the wards. The survey allowed participants to use mobile phones or computers to participate. In addition to the questions on the validated UEQ tool, occupational data (job position and experience using eCCR) were collected to classify the end users. Two open ended questions were also included asking participants what aspects of the eCCR they disliked and if they had any suggestions. The data collected were kept in a private access-control computer where only the supervisor and investigator had access.

2.6 Data Analysis

Data from the electronic questionnaire was directly entered into UEQ data analysis tool, embedded with a Microsoft Excel™ spreadsheet. Themes were identified from the comments to the open-ended questions.

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2.6 Data Analysis

Data from the electronic questionnaire was directly entered into UEQ data analysis tool, embedded with a Microsoft Excel™ spreadsheet. Themes were identified from the comments to the open-ended questions.

The UEQ tool included functions to automate and analyse the data returned from Microsoft Forms™. It used six scores for *attractiveness*, *efficiency*, *perspicuity*, *dependability*, *stimulation*, and *novelty* to evaluate UX (Fig.1). Descriptive statistics were used to report the mean, variance, and standard deviation of scores and per item asked. The data on occupational roles and months of experience were presented using frequency tables, bar, and pie charts. The UEQ analysis measured the means of grouped UEQ scale qualities and individually scales, reported standard deviation (SD), 95% confidence intervals (CI) and benchmarks. Furthermore, the participants were grouped in the months of using eCCR Group 1-6 months, Group 6-12 months, and Group >12 months. The association between the months (experience) of using eCCR and UX was analysed using the ANOVA F-test. A p-value of <0.05 was considered statistically significant.

2.7 Ethics considerations

This study was conducted according to accepted and applicable national and international ethical guidelines and principles, including those of the international Declaration of Helsinki, seventh revision of 2013 [27]. Health Research Ethics Committee at Stellenbosch University provided ethics approval (S22/08/155). Furthermore, the WCGHW Provincial Health Research Committee granted permission to conduct the research (WC_202212_015), as well as the joint proprietors of the eCCR application.

A consent form was integrated into the online survey. After informed consent was obtained, the participants were enrolled into the study and had access to the UEQ. Personal details were stored separately from questionnaire responses according to South Africa's Protection of Personal Information Act of 2013.

3 Results

There were 208 respondents to the survey, of which five did not meet inclusion criteria and two declined providing consent. Therefore 201 participants were analysed. Participant professional roles and demographic characteristics are outlined in Table 1.

Table 1. Participant roles and demographics (n = 201)

Professional roles	Frequency	Percentage
Senior Clinicians	98	48.75%
Junior Clinician	82	40.79%
Nurse	6	2.99%
Allied Health Worker	5	2.49%
Clerk	3	1.49%
Case Manager	2	1.00%
Administrator	5	2.49%
Age Range	Frequency	Percentage
24-30	77	38.31%
31-40	69	34.33%
41-50	32	15.92%
51-60	19	9.53%
61-65	4	1.99%

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The sample had 157 (77%) participants with more than 12 months using the application, 6 to 12 months 19 (9%), 1 to 6 months 23 (11%). The participants were aged between 22 to 64.

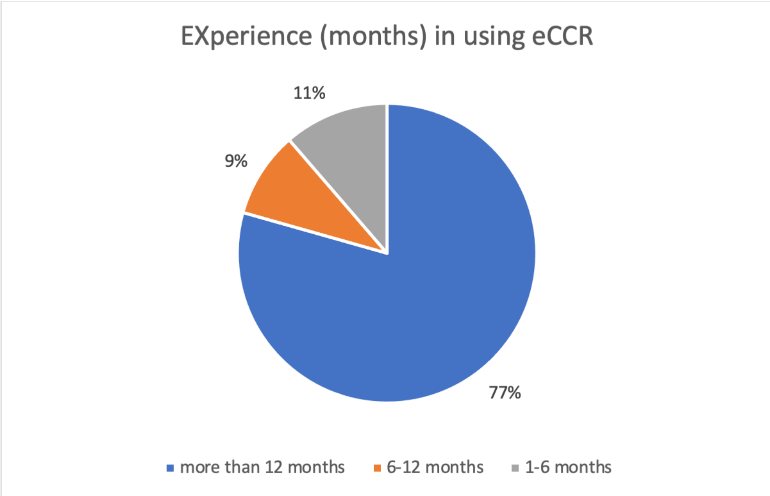

Figure 2. Healthcare workers' experience in using eCCR (months)

3.1 User Experience Questionnaire results

The UEQ toolkit includes a Microsoft Excel™ based analysis formulas to analyse the data. The results below were outputs of UEQ analysis tool. The table below presents the means of UEQ scales grouped into pragmatic and hedonic quality, pragmatic quality (Perspicuity, Efficiency, Dependability) and hedonic quality (Stimulation, Novelty). The mean values between -0.80 and 0.80 represent neutral experience of the corresponding scale, values > 0,80 represent a positive experience and values < -0,80 represent a negative experience.

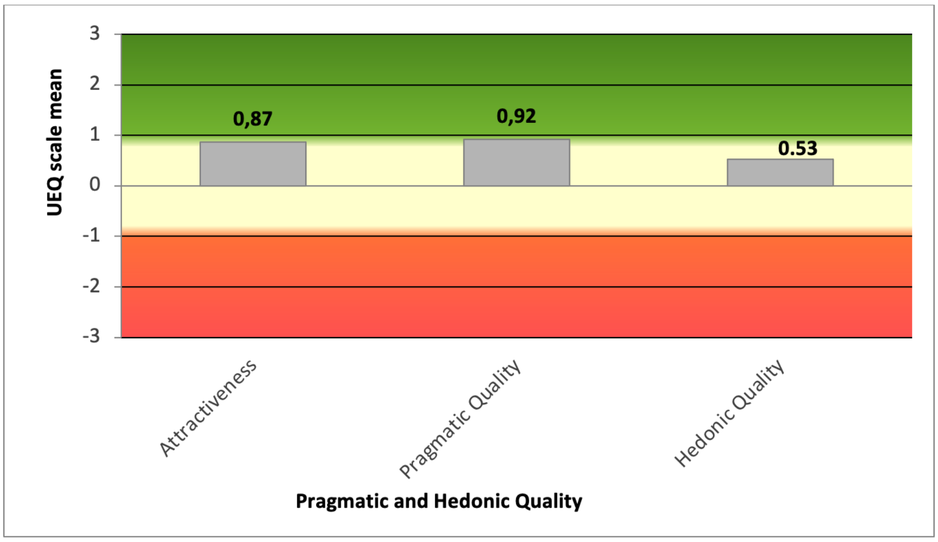

Figure 3. Grouped User Experience Questionnaire scale

The analysis of the means of the six scores found *perspicuity* (1.32) had a highest mean, followed by *attractiveness* (0.87) and *dependability* 0.89, indicating positive experiences. The *stimulation* 0.76, efficiency 0.55 and *novelty* 0.30 had means below 0.80, indicating a less than neutral experience.

Table 2. User Experience Questionnaire descriptive statistics (n = 201)

Scale	Mean	Std. Dev.	95% Confidence Interval
Attractiveness	0.87	1.30	0.69 – 1.05
Perspicuity	1.32	1.10	1.17 – 1.48
Efficiency	0.55	1.23	0.37 – 0.72
Dependability	0.89	1.17	0.73 – 1.05
Stimulation	0.76	1.21	0.59 – 0.93
Novelty	0.30	1.13	0.14 – 0.45

The 95% confidence intervals for the six scales are presented on the table above, including means and standard deviation. The confidence interval is a measure for the precision of the estimation of the scale mean.

The UEQ analysis performs a benchmark comparison of the quality of the product evaluated compared to other products. The benchmarks allow conclusions about the relative quality of the evaluated product compared to other products. Below are the results of how the eCCR compared to other products tested using UEQ.

The eCCR benchmarks ranged from above average to bad. Four of the scales ranked below average. *Perspicuity* was the only scale that ranked above average, while *efficiency* had the lowest benchmarking rank.

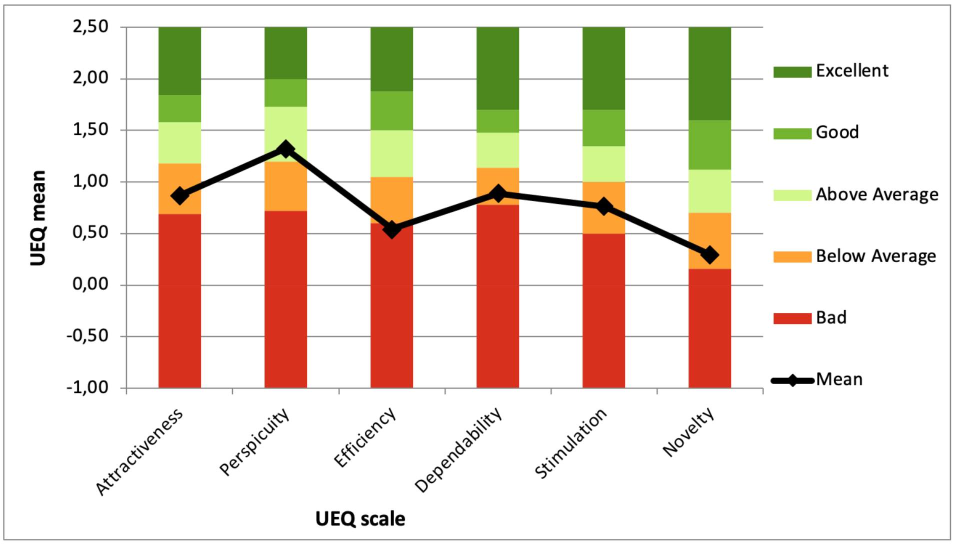

Figure 4. eCCR Benchmark when compared to other applications that were assessed by the UEQ.

3.2 Association between user characteristics and the UX of eCCR.

Further statistical analysis was done to assess the association between months of using eCCR and UX (UEQ scale means between the three groups. The table below presents the means, SD, and 95% confidence intervals within each group. The difference in the UEQ means between the three groups had no statistical significance.

Table 3. ANOVA descriptive analysis between the three groups of months using eCCR.

	Months using eCCR	n	Mean	SD	95% confidence interval of mean	p-value
Attractiveness	1 – 6 months	23	0.79	1.36	0.20 – 1.38	
	6 – 12 months	19	0.43	1.20	-0.15 – 1.01	
	>12 months	159	0.93	1.30	0.73 – 1.14	
	Total	201	0.87	1.30	0.67 – 1.05	0.27
Perspicuity	1 – 6 months	23	1.27	0.87	0.88 – 1.64	
	6 – 12 months	19	1.35	1.21	0.77 – 1.94	
	>12 months	159	1.33	1.12	1.15 – 1.50	
	Total	201	1.32	1.10	1.17– 1.48	0.96
Efficiency	1 – 6 months	23	0.43	1.32	-0.13 – 0.99	
	6 – 12 months	19	0.53	1.33	-0.11 – 1.17	
	>12 months	159	0.56	1.21	0.37 – 0.75	
	Total	201	0.54	1.23	0.37 – -0.72	0.89
Dependability	1 – 6 months	23	0.71	1.22	0.18 – 1.23	
	6 – 12 months	19	0.64	1.31	0.01 – 1.28	
	>12 months	159	0.94	1.15	0.76 – 1.12	
	Total	201	0.89	1.17	0.72 – 1.05	0.42
Stimulation	1 – 6 months	23	0.49	0.99	0.06 – 0.92	
	6 – 12 months	19	0.34	1.44	-0.35 – 1.03	
	>12 months	159	0.85	1.19	0.66 – 1.03	
	Total	201	0.76	1.20	0.59 – 0.93	0.12
Novelty	1 – 6 months	23	0.34	0.84	-0,03 – -0,70	
	6 – 12 months	19	0.18	0.93	-0.27 – 0.63	
	>12 months	159	0.30	1.19	0.11 – 0.49	
	Total	201	0.29	1.13	0.14 – 0.45	0.90

3.3 Suggestions to Improve the User Experience of the eCCR Application

In response to the open question about what research respondents dislike about the application, they reported that the eCCR application was slow, that they were frustrated with the use of ICD codes and disliked having to manage multiple sets of credentials across the various clinical applications available to them. They suggested improving the eCCR application's speed, improving the ICD coding user experience, and enabling integrated access to all clinical information about their patients.

4 Discussion

Although the eCCR was available to a diverse range of health professionals in the public hospitals, the study appealed to younger professionals between the ages of 20 to 40. This is likely because discharge summaries were commonly prepared by the younger junior clinicians. Previous surveys have also reported decreased survey response rate from the clinicians as their age increased. One study suggested that the higher workload could be forcing them to prioritize their clinical duties and postpone other activities, like answering surveys [28].

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This finding from this UX evaluation suggests that the longer the users use an application, the more their UX improves [11]. In this study participants with less than one month's experience were excluded. 11% of the participants had used the application for between one and six months. More than 75% of the participants had used eCCR for more than 12 months. Since three quarters of the sample had more than 12 months of experience, we can assume that these users were more familiar and comfortable with the eCCR.

End users rated the *attractiveness* as a positive experience, meaning that they perceived the eCCR to be pleasant, good, user-friendly, and enjoyable to use.

4.1 Pragmatic quality

The UEQ scale means, grouped into pragmatic quality, indicated an overall positive experience by users. The participants indicated the application was easy to use and understandable as the *perspicuity* had a highest mean. This is a good finding, since the WCGHW department has been using and improving this application for more than eight years and has eliminated the need for special training that would draw clinicians away from their core clinical duties. The *dependability* scale also had a positive finding. The eCCR proved to meet the expectations of the end users. Users perceived the web-based application to be predictable and secure.

Regarding the *efficiency* of the eCCR, the results indicated participants had a neutral experience when looking at whether the application was fast or slow, efficient, or inefficient, or practical or impractical. The *efficiency* scale had the lowest mean in the pragmatic quality group. Additionally, when compared to other applications, the *efficiency* was reported as bad. While users reported that the application was slow, it may have been difficult for them to distinguish between the overall network speed and the eCCR responsiveness. Similarly, the eCCR *dependability* scored below average. Only *perspicuity* scored well compared with other applications.

Hassenzahl stated that, if end users perceive a product or application to be effective and efficient, they will be satisfied with their UX [5][6]. Although the participants reported positive experiences for *perspicuity* and *dependability*, *efficiency* of this application did not meet end users' expectations. However, the adoption of the eCCR in the Western Cape has been good despite literature that suggests that poor aspects of systems features would slow down the adoption of the EMR [29].

4.2 Hedonic quality

The hedonic quality of the eCCR had a low UEQ scale mean. The participants found the sensational aspects of the eCCR to be a neutral rather than a positive experience. The analysis outputs indicate that the eCCR is not very interesting, creative, and innovative. Although the pragmatic quality was rated better than the hedonic quality of this application, users will benefit from further development focusing on improving hedonic quality. The *stimulation* was rated better than the *novelty.* The application is valuable to the end users. The eCCR has a valuable function in the health system, and the healthcare professionals value its role.

The *novelty* scale had the lowest UEQ scale mean of all the six scales. The end users reported this web-based application was not very innovative, creative, or leading-edge. When compared to other applications on the UEQ, benchmarks *stimulation* and *novelty* were reported to be below average. There is a significant requirement for the eCCR developers and management to reevaluate the hedonic features of this application.

4.3 End users grouped by months using eCCR

The ANOVA test did not demonstrate statistically significant findings between the different groups of the UEQ scale means, but the study may have been underpowered for this as a secondary objective. This study excluded end users who had not used the application for longer than one month.

4.4 Limitations

The study was impacted by a lower-than-expected survey response rate which is a common limitation in surveys in general [26][28]. The inability to remind participants to take the survey made it difficult to motivate participants. The investigators emailed hospital managers with requests to encourage their clinical staff to participate and posted study promotion posters in areas that would be visible to clinicians.

In terms of the internal validity, the inherent design and layout of the UEQ, as a validated questionnaire, was to reduce respondent bias. However, there may have selection bias as this survey primarily targeted current users of the application and inadvertently excluded past eCCR end users who may have disengaged from the application due to poor UX.

Regarding external validity, the findings of this study are specific to the eCCR application. However, custodians of similar applications within South Africa's expanding digital health space may take heed of potential pitfalls as they strengthen their respective applications. While this study focussed on the UX of a specific EMR application in the Western Cape, it provides proof of concept for use of the UEQ within the South African public health sector.

4.5 Recommendations

For future enhancements to this eCCR, the developers should focus on improving the hedonic qualities of the application to make it more innovative, creative, and interesting. Attention should be given to the speed and responsiveness of eCCR and/or the network infrastructure on which the application runs.

5 Conclusion

Overall, the users perceived the UX of the eCCR application as a positive experience. This UX evaluation indicated that the eCCR was an easy-to-learn and understandable web-based application. The end users reported that it was valuable, secure, enjoyable, and met most of their expectations. The overall attractiveness of application was positive.

Although the benchmarking scores of the UX of eCCR were positive, some of the scales were below average with efficiency reported as poor. There were aspects in need of strengthening to make the application more efficient, innovative, and creative to improve the UX.

The findings of this study will guide the future developments of the eCCR in the Western Cape and assist other health organisations in developing or improving their EMRs. Furthermore, this research demonstrates the value of evaluating UX in multi-dimensional and constructive manner with a view to strengthening EMR applications within South African digital health ecosystem.

Acknowledgements

The investigators wish to express their gratitude to the Western Cape Government: Health and Wellness department employees who were involved in this project.

We acknowledge Health System Technologies (HST), developers of the eCCR, for agreeing to the UX evaluation of this application.

Thank you to the Prof Martin Schrepp and the UEQ team for developing an easy-to-use questionnaire and analysis tool (https://www.ueq-online.org/).

Declarations

The research for this study was done in partial fulfilment of the requirements for MPhil in Health Systems and Research Services degree at Stellenbosch University.

Conflict of Interest

None.

Author Contributions

SG and RD conceptualised the study. SG conducted the data collection, analysis and drafted the manuscript. RD supervised the research. Both authors critically reviewed the manuscript and approved the final version for publication.

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An Exploration of Opportunities for Quantified-Self Technology in Diabetes Self-Care: A Systematic Literature Review

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Background and Purpose: To avoid the adoption of quantified-self technologies for diabetic self-care by trial and error, this study investigated quantified-self opportunities. The premise of the study was that the adoption of quantified-self technologies should be preceded by knowledge of the opportunities that are provided by the technology. In this respect, the research search question was, 'What are the opportunities for the use of quantified self technology in the management of diabetes in developing countries?'.
Methods: A systematic literature analysis was carried out to answer the research question. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were followed to select articles from four databases, which are PubMed, ProQuest, Web of Science and Science Direct. A total of 50 peer-reviewed journal and conference articles published between 2018 and 2024 were analysed.
Results: Literature analysis uncovered four opportunities for using quantified-self technologies in the management of diabetes. Opportunities include monitoring, adherence, reduced cost, and data collection and sharing.
Conclusions: The identified opportunities are informative and empower diabetic patients with knowledge that helps them with decision making prior to the adoption of quantified-self technologies for diabetic self-care. The results of this study are equally applicable to the adoption of any other technology, as it is important that the opportunities brought by a technology should be known before its adoption.

Keywords: diabetes, quantified-self technology, self-care, self-tracking, personalised treatment

1 Introduction

Diabetes is acknowledged as a chronic disease that is influenced by one's lifestyle and requires strict adherence to self-care practices [1]. Adherence requires strict self-management of routines that include diet, physical activities, medication, and blood glucose monitoring [2]. Keeping up with self-care routines is difficult due to several reasons, for example, pressure at work, life, or amnesia. Until now, research has confirmed that adherence to self-care routines has a significant impact on reducing diabetes attacks and emergency admissions in hospitals [3] [4]. Ellahham [3] confirmed that the self-management of diabetes can be improved by using artificial intelligence (AI) technologies that can help monitor the disease, of which quantified-self is one of those capabilities.

The term quantified-self refers to individuals who participate in the self-monitoring of various types of biological, physical, behavioural, or environmental data, which is perceived as a natural phenomenon because people always collect data about themselves [4]. Research has found that quantified-self technologies can collect data that includes eating habits, physical activity, taking medicine, sleeping patterns, and monitoring diseases [5][6]. Data collection is facilitated by quantified-self gadgets that include wristwatches, smartphones and other wearable digital devices [2][7][8].

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Although the literature has shown that the use of quantified-self tools is substantial in improving self-care for chronic diseases, its adoption in developing countries is not well-documented [9][10]. Mutunhu et al. [9] argued that to strengthen the adoption of self-monitoring technologies in developing countries, it is important that opportunities to use technology in the management of diabetes are identified and shared. Opportunities are prospects/situations brought about by quantified-self technologies that enable diabetic people to self-manage their ailments. Therefore, this study employed a systematic literature analysis to explore the opportunities of quantified-self technologies in the management of diabetes for the benefit of patients in developing countries. To this end, the premise of the study was that the adoption of quantified-self technologies should be preceded by knowledge of the opportunities that are provided by the technology. The premise was translated into the following research question, which is investigated this study, 'What are the opportunities for the use of quantified-self technology in the management of diabetes in developing countries?'. The results of this study are informative, uncovering quantified-self technology opportunities that citizens of developing countries need to know to integrate and benefit from quantified-self technology in the management of diabetes.

The remainder of this paper is organised as follows, Section 2 presents the background studies on quantified-self technology and identifies the gap in knowledge, Section 3 presents the methods, Section 4 presents the results, Section 5 presents the discussion, and Section 6 the conclusion of the study.

2 Quantified-Self Technology Background

This study reviewed fifteen peer-reviewed systematic literature analysis published articles on quantified-self technology adoption [10][11][12][13][14][7][15][16][17][18][19][20][9][21][22]. The analysis found that the first article on quantified-self technologies was published in 1990 [12], however, Kelly and Wolf are attributed to have founded the quantified-self phenomenon in 2007 [4]. Although the analysis found varied results from the articles, most investigated the adoption of quantified-self technologies within the health and well-being of individual people, and patients under health care practitioners. Concerning well-being, many articles investigated applications of quantified-self in tracking sports, daily activities, diet, and sleeping patterns [7][15]. For studies that applied quantified-self technology in health, it was found that it can be used to enforce adherence to medication, diet, and monitoring blood glucose levels [12].

The analysed studies revealed motivations for using quantified-self technology [14][13][15][22]. Jiang and Cameron [13] identified motivations as behaviour change, compliance, improved health, rewards, and self-efficacy. In addition, quantified-self technology was found to be helpful in goal-setting [21][19][20].

Three papers focused on the design of quantified-self applications [11][18] [14]. Lentferink [11] found that a well-designed quantified-self application should be usable, persuasive, and provide affordance. Regarding design, Epstein et al. [14] found that self-tracking applications should be designed to change behaviour and encourage social connection between users.

Two papers discussed the ethics of using quantified-self applications [14][10]. The papers discussed issues of identity protection and data sharing with friends/ family through social media. It was revealed that if quantified-self data end up in the wrong hands, it may be misused against the person. In that respect, both studies recommended that the design of quantified-self applications should consider issues of privacy, security, and ethics.

Future research is recommended to focus on ethics [23][14], attitudes, barriers [7][23], social-cultural contexts [23][10], theoretical frameworks [23][14][13] and opportunities for quantified-self in diabetes self-care [9][21][24]. This study builds on Mutunhu et al. [9], and is backed by a gap in knowledge identified from an analysis of theoretical underpinnings of quantified-self studies. Of the 50 studies analysed in this study, 14 articles presented in Table 1 had underpinning theories. An analysis of the constructs of the underpinning theories uncovered that none had a construct that explicitly focused on identifying opportunities brought by technology. This indicates that the studies that were analysed in this study did not investigate the opportunities of quantified-self technologies in the self-care of diabetes. Based on the identified gap in knowledge, this study investigated the opportunities offered by quantified-self technology in diabetes self-care.

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Table 1. Quantified-self technology studies with theoretical underpinnings

Theory	Constructs	Studies that adopted the theory
Cognitive-affective-social-motivational model	• perceived usefulness • perceived ease of use • Effectiveness • feelings • social images	[25]
Unified Theory of Technology Acceptance and Use of Technology (UTAUT)	• performance expectancy • effort expectancy • social influence • facilitating conditions • gender • age • experience • voluntariness of use • behavioural intention • use behaviour	[26] [27][28][29]
Unified Theory of Technology Acceptance and Use of Technology 2 (UTAUT2)	• performance expectancy • effort expectancy • social influence • facilitating • hedonic motivation • price value • Habit • Age • Gender • experience • behavioural intention • use behaviour	[30][31]
Extended Valence Theory (EVT)	• utilitarian value • perceived risk • perceived return • trust • intention to purchase	[16]
Self Determination Theory (SDT)	• autonomy • competence • relatedness • Intrinsic motivation • Extrinsic motivation	[32]
Cognitive Motivation Relational Theory	• cognitive appraisal • emotional response • behavioral reactions • individual factors	[33]
Social Cognitive Theory	• personal factors • behaviour • environment • Reciprocal Determinism • Behavioural Capability • Observational Learning • Reinforcements • Expectations • Self-efficacy	[34] [35]

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Revised TAM model; Diffusion of Innovation; Self Efficacy; Social Exchange Theory	• perceived usefulness • perceived ease of use • Embedded Technology Self-Efficacy • Gender • Age • Perceived Risk • Privacy Concerns	[36]
Technology Acceptance Model; Health Information Technology Acceptance Model; Mobile Application Rating Scale	• Engagement • Functionality • aesthetics • information quality • Perceived ease of use • Perceived usefulness • Perceived disease threat	[37]

3 METHODS

This systematic review used the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) protocol [38]. Adhering to PRISMA, the research systematically identified, selected, screened, examined and summarised published research articles on the opportunities provided by quantified-self technology in the management of diabetes.

3.1 Data Sources and Search Strategy

A comprehensive search was carried out in the year 2024 across the following five databases that host peer-reviewed articles: PubMed, ProQuest, Science Direct, and Web of Science. The search strategy encompassed variations and synonyms of keywords: "quantified self" and "diabetes".

(("lifelog" OR "life-log" OR “self-monitor*” OR “self monitor*” OR “self-track*” OR “self track*” OR “quantified self” OR “quantified-self” OR “self quantif*” OR “self-quantif*”) AND "diabet*")

However, due to the syntax discrepancies, the constructed search term was altered to align with the requirements of each database.

3.2 Inclusion and exclusion criteria

The inclusion and exclusion criteria are delineated in Textbox 1. To further strengthen the article search's overall comprehensiveness, citation chaining was done.

INCLUSION CRITERIA
- Studies published between 2018 and 2024.
- Research articles disseminated in the English language.
- Full text articles.
- Research findings published in a peer-reviewed scholarly journal and conference proceedings.

EXCLUSION CRITERIA
- Commentary pieces, editorials, and grey literature
- Studies on quantified-self technology but not focused on healthcare
- Studies not discussion quantified-self technology opportunities in healthcare
- Research using non-human primary empirical subjects, like goods, services, or marketplaces
- Non-peer-reviewed studies that include unpublished manuscripts, conference abstracts, and studies not undergoing rigorous peer review

Textbox 1: Inclusion/exclusion Criteria

3.3 Screening

A total of 2831 articles were selected from the four databases, 41 articles from PubMed, 32 articles from Science Direct, 1589 articles from ProQuest, and 1169 articles from Web of Science. A total of 762 duplicates were eliminated, and, furthermore, 1724 were excluded because they did not meet the inclusion criteria. The abstracts, keywords, and conclusions of the remaining 345 articles were analysed, and 248 articles were excluded. There were 97 articles that met the inclusion criteria and were analysed by two researchers. The two researchers read through the 97 articles thoroughly and agreed that 47 articles did not meet the inclusion criteria. The remaining 50 articles were fully analysed by the researchers.

4 RESULTS

The results of the article selection are presented in a PRISMA flow chart in Figure 1. The flow diagram shows the selection process and the number of articles searched per database.

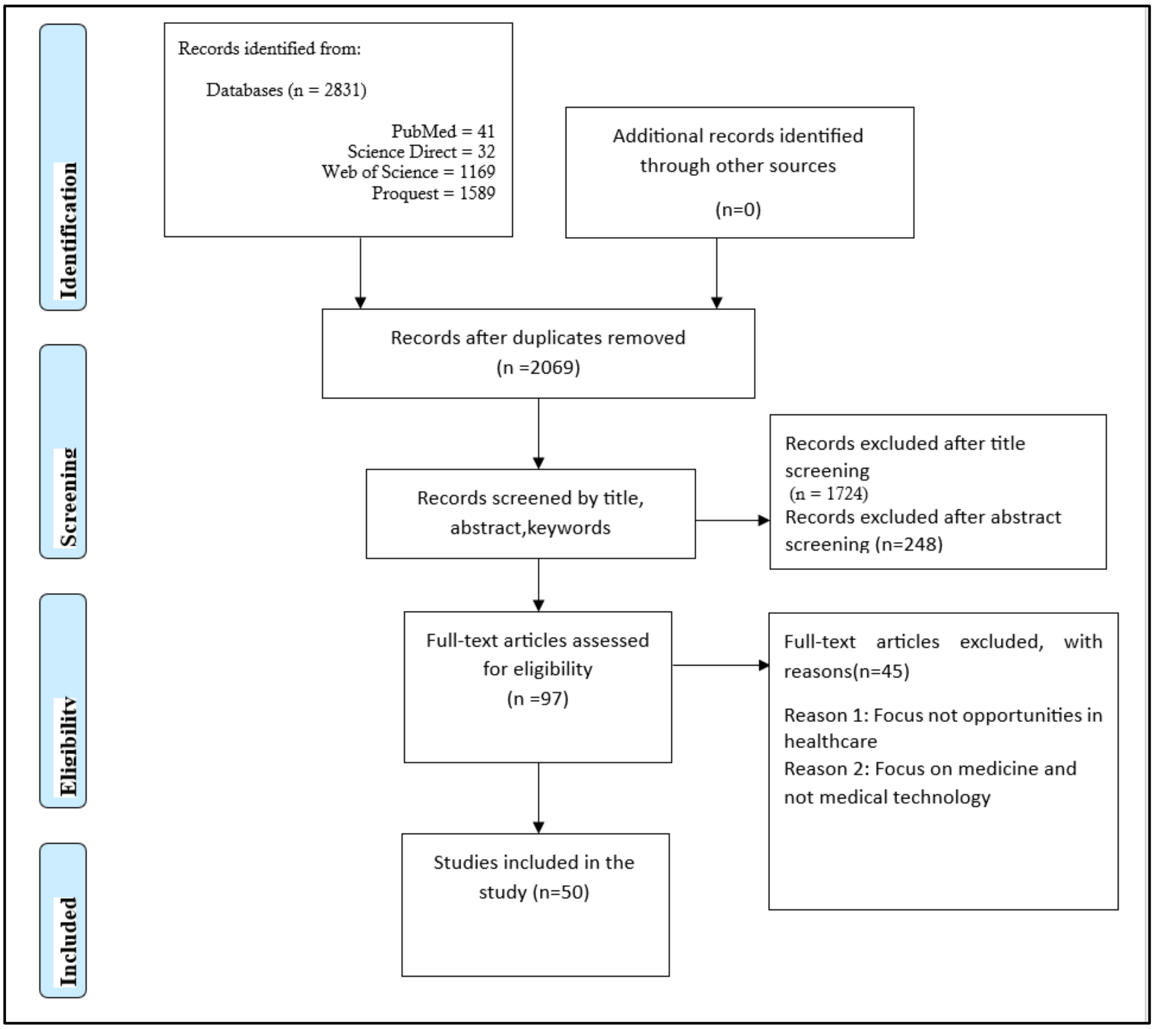

Figure 1. PRISMA 2020 flow diagram

4.1 Reviewed Articles

Table 2 provides a summary of 50 articles that were reviewed in this study. It identifies the opportunities for quantified-self technology in healthcare and gives a list of references. Table 2: Quantified-self technology opportunities

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Table 2. Quantified-self technology opportunities

OPPORTUNITY (Main theme)	**SUB OPPORTUNITY (Sub-theme)**	**REFERENCES**
Monitoring	Chronic disease monitoring	[28] [39] [40] [41] [42][43] [44] [45] [46] [47] [48][37] [49] [31] [50] [51] [6] [52] [53] [54] [55] [56] [57] [52] [58] [37] [59] [60]
	Disease tracking	[61] [32] [62] [48] [15] [2] [52] [62] [63]
	Monitoring treatment	[42] [31] [55] [63] [52] [64] [65] [48]
	Monitoring of physical activities and exercise	[24] [33] [61][48] [61]
Adherence	Reminders to take medication	[52] [55] [44] [59] [28] [50] [66] [51] [62] [37]
	Medical refill reminders	[26] [56] [42] [67] [68] [69]
Data Collecting and Sharing	Personalised Feedback	[52] [53] [33] [59] [57] [29] [68] [64] [2] [35] [64] [57] [35]
	Trend analysis of the disease	[69] [65] [47] [44] [59] [60] [50] [6] [56] [54] [64]
	Disease prediction analysis	[2] [41] [35] [29] [55] [56] [64]
	Patient-Physician data sharing	[67] [52] [62] [49] [69] [70]
Cost reduction	Reduced hospitalisation/visits to the clinic	[29] [49] [40] [26] [70] [67]
	Reduced healthcare care cost	[63] [71] [48] [49] [60] [30] [15] [55] [6] [56] [34] [25] [32]

4.2 Year of publication

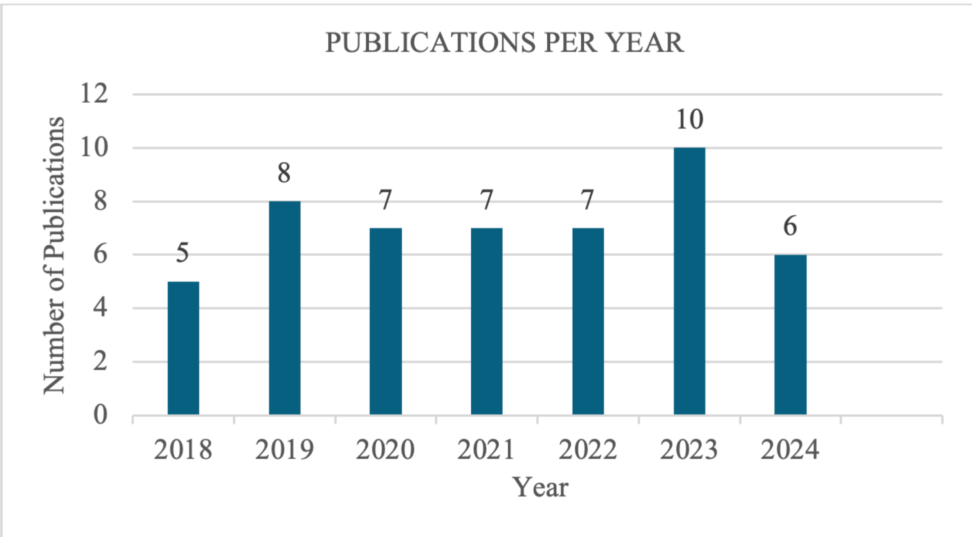

Figure 2 : Publications per Year

Figure 2 shows the annual publication trends of the analysed quantified-self articles. There appears to be a gradual peak in publications from 2018 (5) articles to 2023 (10) articles per year, showing a growing trend in quantified-self research. Although there is a general growth, some negative growths were observed between some of the years. Fluctuations could be due to that research on the quantified-self is still new and has not reached equilibrium. The lower number of publications in the year 2024 (6) could be because the year is now halfway (June), and more papers could not have been published.

4.3 Country where research was conducted

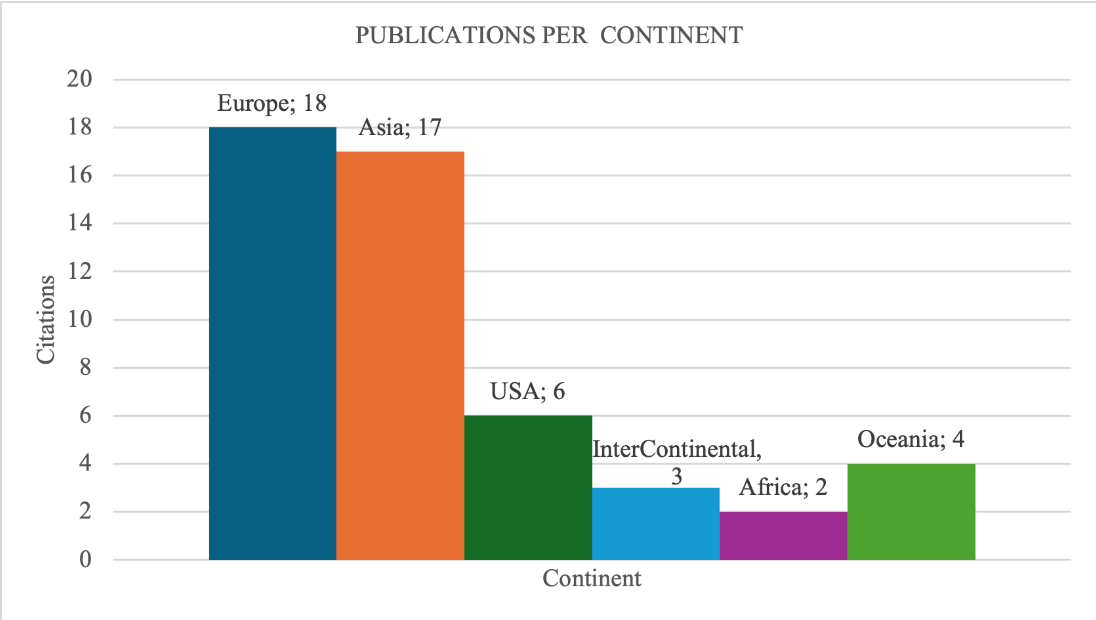

Figure 3. Frequency of Publications per Continent

Figure 3 shows that most of the publications are from Europe and Asia, with 18 and 17 publications, respectively. The two continents seem to be leading the research on quantified-self with over 80% of the total publications. There is low representation from the USA, Africa, and Oceania, with 6, 2, and 4 publications, respectively. There were four publications classified as inter-continental showing collaboration among academics from different continents.

4.4 Opportunities for Quantified-Self Technology

Opportunities for the use of quantified-self technology in the management of diabetes are depicted in Figure 4. The graph shows the four main opportunities that were identified from the literature analysis, monitoring, data collection & sharing, cost reduction, and adherence. The opportunity that was mentioned in most articles was monitoring, appearing in 36 articles, and the opportunity with the least appearances was adherence, featuring in 15 articles.

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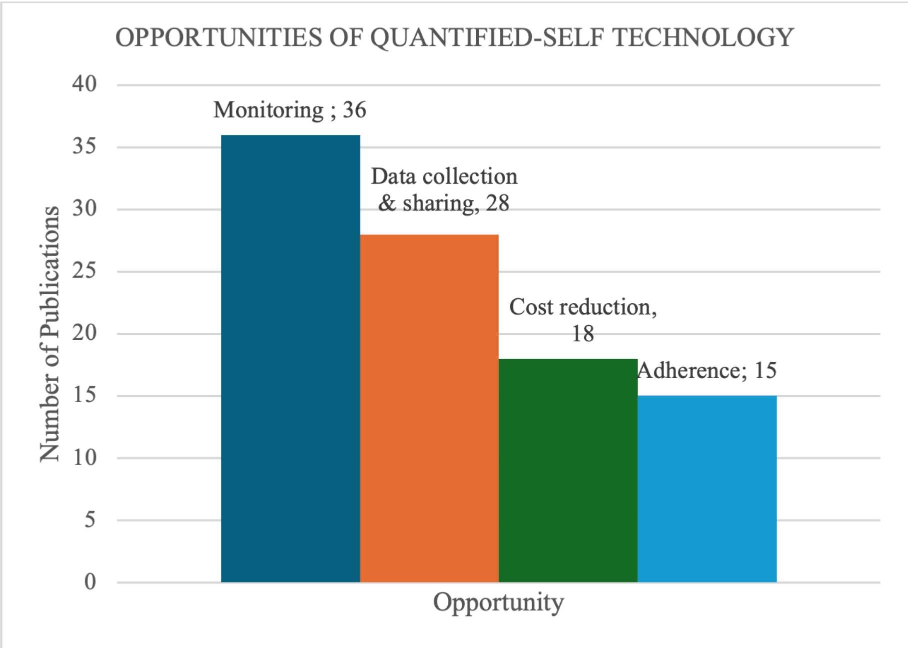

Figurw 4. Opportunities of quantified-self technology

5 Discussion

This section discusses quantified-self technology opportunities and relates them to practical use cases of diabetic self-care management. This section answers the research question investigated in this study 'What are the opportunities for the use of quantified-self technology in the management of diabetes in developing countries?'. The opportunities identified from the systematic literature analysis are monitoring, adherence, reduced cost, and data collection and sharing. These opportunities are now discussed.

5.1 Monitoring

Quantified-self technology allows people with diabetes to monitor a wide range of health parameters, including blood sugar levels, blood pressure, exercise, diet, cholesterol, and stress [59]. Physiological monitoring provides information on glucose level fluctuations, which facilitates timely interventions if abnormalities are observed [48][52]. Various studies have shown the importance of quantified-self technology as an enhancer of self-care among diabetic patients tracking their ailments [44][45][40][61]. For example, in a case study of a self-tracking diabetic patient [61], the patient stabilised the blood sugar level by following a strict self-tracking routine involving diet and exercise. In a study carried out in New Zealand [42], quantified-self technologies were reported to have provided positive results in glucose monitoring, leading to improved health behaviours. In another study carried out in Sweden, quantified-self technologies provided positive results in monitoring motor symptoms, stress levels, dietary habits, and sleep [52]. Furthermore, studies carried out in Germany [34] and the Netherlands [62] found that using quantified-self technologies for fitness tracking was significant in improving physical fitness and glycaemic control compared to non-users. These case studies supported that quantified-self technologies can provide an opportunity for physiological monitoring in diabetic patients.

5.2 Adherence

There is a complex interplay of factors that affect the adherence to the taking of chronic medications by diabetic patients [73] [74]. Two factors that negatively affect adherence are forgetfulness and time management, which can lead to mortality [72]. Time management is complicated in situations where

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patients are required to take multiple drugs at different intervals [56]. To overcome the challenges of forgetfulness and time management, which are prevalent in young and old people, some research in health informatics has shown that implementing quantified-self based reminders can provide lasting solutions [26][42][44][68][67]. In addition, quantified-self technologies can track medication intake, dosages, and schedules helping patients to adhere. Ajana [71] claimed that quantified-self technologies can remind users through alarms to take medication, exercise, or increase their water intake. Furthermore, some studies [44][68] confirmed that improved adherence positively improves morbidity, lifestyle, and enhances the autonomy of young and old people. However, a study from India reported that self-tracking technologies were perceived as confusing and costly due to the requirement of frequent blood glucose measurements, leading to non-adherence [50]. In this regard, a study conducted in China [66] called for the implementation of quantified-self technology adoption awareness campaigns as a way to overcome nonadherence to chronic medications.

5.3 Collecting and Sharing Data

Accurate treatment of diabetes requires intensive data collection and analysis, which requires accurate capture, transmission, and interpretation of quality data [73]. In the realm of electronic health, quantified-self technology has been considered as a technology that can facilitate self-assessment [33], trend analysis [17], predictive analysis [64][74] and data sharing [2][22].

Quantified-self technology has the potential to increase health self-awareness in diabetic patients by accurately gathering and analysing physiological data [33]. Through the captured data, patients can receive feedback on their health status, recommendations, and alerts based on their needs [2][7]. In the case of autism management [64], patient data was found to be significant in analysing patterns associated with specific behavioural triggers. If disease patterns are understood in diabetic patients, they empower individuals to make informed self-care decisions, proactively adjust dietary and lifestyle habits, and seek medical assistance immediately when necessary [64] [2] [7]. In line with the findings, there are studies [59] [41] that emphasise that effective management of diabetes necessitates an understanding of how activities and daily routines are proportionally aligned with fluctuations in diabetes. Furthermore, quantified-self technologies allow diabetic patients to share data remotely with physicians, family, peers, or supportive communities[2] [22].

Quantified-self technology redefines patient-physician communication by integrating data from self-monitoring devices [64]. Data provide physicians with comprehensive information on patient health status, facilitating more informed treatment decisions, timely modification of treatment regimens, and ultimately improved diabetes management results [60] [52].

Socially, quantified-self technology can facilitate emotional support for elderly patients, allowing them to participate in virtual communities, exchange experiences, and receive encouragement from peers or caregivers [31]. Online networks provide valuable peer support, allowing people to share insights, pose questions, and learn from others on their diabetes management journey. This alleviates feelings of isolation and improves general well-being, which are crucial aspects of healing [6].

5.4 Reduced costs

Quantified-self technology can improve diabetes management by tracking conditions that lead to diabetes such as diet, physical activity, body weight and other physiological factors [17][64][74]. The literature has provided significant results supporting the notion that quantified-self technologies can provide feedback and recommendations on physiology, diet, and activities that help people lead healthy lives [2] [7]. By having a healthy lifestyle, diabetics can manage conditions that cause diabetic attacks, which means they will not be admitted to hospitals regularly, which in turn reduces hospital bills and associated costs [48] [60]. There are case studies that showed that quantified self-care reduces hospitalisation costs [49] and oral medication costs [61] in diabetic patients. Furthermore, there is research [75][76] that revealed that the adoption of quantified-self technologies is supported by company wellness programs and health insurance, which provides incentives for wearable quantified-self gadgets and insurance discounts. Consistently, there are studies [71] [34] that found that quantified-self technologies encourage healthy living by rewarding those who achieve personalised goals. Rewards provided by quantified-self technology were recognised for persuading users to achieve goals, for example, running several kilometers per day [61][48]. Therefore, the

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incentives and rewards provided for using quantified-self technologies potentially reduce medical costs in the long run.

Quantified-self technology provides an opportunity for telehealth through a variety of applications that enable the collection of self-tracking data, texting, and video conferencing [77]. Telehealth provides remote services such as online consultation, monitoring, and mentoring, which cost less than having a face-to-face medical consultation [78]. Additionally, quantified-self technology facilitates the capture of personal data, for example, heart rate, blood pressure, and glucose test, whose results can be shared remotely and help with remote consultation [79][80]. Data capture by the patient costs less than tests performed in a laboratory.

6 Conclusions

The premise of this study was that the adoption of any technology should be preceded by knowledge of the opportunities that the technology being adopted provides. The premise was contextualised to the adoption of quantified-self technologies in the self-care of diabetes. The research question of the study was 'What are the opportunities for the use of quantified-self technology in the management of diabetes in developing countries?'. The systematic analysis of the literature uncovered four opportunities in which quantified-self technology can be used in the management of diabetes. The opportunities are monitoring, adherence, reduced cost, and data collection and sharing. The identified opportunities are valuable because having prior knowledge before adopting quantified-self technology enables a person to determine if the technology will satisfy their needs. Furthermore, the opportunities are beneficial to citizens of third-world countries who usually adopt technologies with insufficient knowledge of the opportunities that they can benefit from.

This systematic literature analysis study was limited by the number of articles that were analysed. Due to constrained human capacity and time, a larger sample of articles could not be reached. However, quantified-self is a new research field and the contribution made in this study will theoretically contribute to the body of knowledge and practically influence the adoption of quantified-self technologies in diabetic self-care.

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