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Review

Barriers and Facilitators of Technology in Cardiac Rehabilitation and Self-Management: Systematic Qualitative Grounded Theory Review

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Abstract

Background: Dealing with cardiovascular disease is challenging and people often struggle to follow rehabilitation and self-management programmes. Several systematic reviews have explored quantitative evidence on the potential of digital interventions to support cardiac rehabilitation and self-management. However, while promising, evidence regarding the effectiveness and uptake of existing interventions is mixed. This paper takes a different, but complementary approach, focusing on qualitative data related to people's experiences of technology in this space.

Objective: Through a qualitative approach this review aims to engage more directly with people's experiences of technology that supports cardiac rehabilitation and self-management. The primary objective of the paper is to provide answers to the following research question: What are the primary barriers, facilitators, and trends of digital interventions to support cardiac rehabilitation and self-management? This question is addressed by synthesising evidence from both medical and computer science literature. Given strong evidence from the field of Human Computer Interaction that user-centred and iterative design methods increase the success of digital health interventions, we also assess the degree to which user-centred and iterative methods have been applied in previous work.

Methods: A grounded theory literature review of articles from the following major electronic databases was conducted: ACM Digital Library, PsychInfo, Scopus and PubMed. Papers published in the last 10 years, 2009-2019, were considered and a systematic search with pre-defined keywords was conducted. Papers were screened against pre-defined inclusion and exclusion criteria. Comparative and in-depth analysis of the extracted qualitative data was carried out through three levels of iterative coding and concept development.

Results: 4282 articles were identified in the initial search. Following screening 61 articles remained, which were both qualitative and quantitative studies and met our inclusion criteria for technology use and health condition. Out of this, 16 qualitative articles were included in the final analysis. The most common digital interventions were web-based, followed by mobile, tablet, and a combination of web and mobile based systems. Studies of systems that focused on increasing physical activity (n=7) were the most common, followed by systems to facilitate greater connection between patients and care-providers; systems focused on providing remote rehabilitation; and others aiming to empower self-management through educational and motivational features (all n=3). Key factors that acted as barriers and facilitators were: background knowledge and in the moment understanding; personal responsibility and social connectedness; and the need to support engagement whilst avoiding overburdening people. While some studies applied user-centred methods, only 6 involved users throughout the design process. There was limited evidence of studies applying iterative approaches.

Conclusions: The use of technology is acceptable to many people undergoing cardiac rehabilitation and self-management. While background knowledge is an important facilitator, technology should also support greater ongoing and in the moment understanding. Connectedness is valuable, but to avoid becoming a barrier technology must also respect and enable individual responsibility. Personalisation and gamification

can also act as facilitators to engagement, but care must be taken to avoid overburdening people. Further application of user-centred and iterative methods represents a significant opportunity in this space.

Keywords: Telemedicine; cardiovascular diseases; self-management; selfcare; systematic review; grounded theory

Introduction

Cardiovascular diseases (CVD) is the number one cause of death globally. An estimated 17.9 million people died from CVD in 2016, representing 31% of all global deaths [1][2]. By 2035 more than 130 million adults in the US population (45.1%) are projected to have some form of CVD, with the total costs of CVD expected to reach \$1.1 trillion [3].

Improved cardiovascular outcomes depend largely on how well affected people manage their condition [4]. Physical rehabilitation and lifestyle management are critical components of programmes aimed at primary and secondary prevention of CVD. A major challenge in implementing these strategies is ensuring good patient engagement and compliance with prescribed exercise programmes and nutrition plans. Evidence from the literature suggests that tightly supervised intervention programmes are most successful and that self-directed management is less successful, due to problems with engagement and adherence. The problem lies in expecting patients with a wide variety of life patterns and personality types to conform to standardized programmes that do not fit with their ever changing context [5].

After a person is hospitalised, and following a discharge and recuperation period, they are typically recommended to attend a cardiac rehabilitation program offered by hospitals. Following this they need to continue to self-manage their cardiac health. Cardiac rehabilitation is considered a vital part of long term recovery by targeting risk factor modification, supervised exercise, psychological support, and medication review [6]. However, uptake of cardiac rehabilitation programs remains poor due to factors including age, gender, lack of knowledge, transportation, motivation, and social support [7][8]. This also has an impact on people's subsequent ability to self-manage their condition. Barlow et al. states: "self-management refers to the individual's ability to manage the symptoms, treatment, physical and psychological consequences and lifestyle changes" [9]. Recent research suggests that digital health interventions can play an important role in supporting both rehabilitation and self-management. A systematic review of mobile phone apps to support self-care following heart failure by Athilingam et al. [10] demonstrated positive trends and cost-effectiveness, enabling increased access to symptom monitoring and promoting patient engagement in their own homes. Similarly, a review by Piette et al. [11] on mHealth technologies for CVD reduction and management found evidence that mHealth interventions can improve cardiovascular-related lifestyle behaviors and disease management. The authors emphasise the need for new interventions that build on evidence-based behavioral theories and are adaptive to a patient's unique and changing needs. Jörntén-Karlsson [12] also suggest mHealth as an effective long-term alternative to face-to-face rehabilitation and consultation, with the potential to reach more patients at a relatively lower cost. They found evidence that digital interventions can have a positive impact on patients with CVD, but again stressed the need for easy to use, personalized and user-friendly applications that can cater to patients from all age groups, especially older age groups. This recognition of the specific needs of older adults is critical, given the significant impact of CVD amongst this age group. However, recognising the potential of technology to support patients with CVD across diverse age groups is also important, given evidence from Foster et al. [13] and Andersson et al. [14] that CVD impacts adults in all age groups. In line with this, a survey conducted by Gallagher et al. [15], to assess the use of mobile technology among

different demographics, demonstrates that mobile technology, when modified to suit different subgroups, offers an important opportunity to improve access to secondary prevention for cardiac patients.

While there is a significant literature and a growing number of reviews on digital interventions for CVD rehabilitation and management, most previous studies base their conclusions on quantitative data. In order to better understand what drives the effectiveness and usage of technologies there is also a need to analyse the collective perspectives of patients', focusing on their experiences, needs, and the barriers they face in using digital interventions. The literature outlined above has provided evidence that personalisation [16] and the application of appropriate theory will play an important role in improving digital health technologies that target CVD. For example, behaviour change theories and models can help inform the design of technical systems, guide evaluation strategies, and define target users [17][18]. In addition, persuasive design patterns can be used in digital interventions to address the challenge of obtaining sustained user engagement and behaviour change among CVD patients [19]. Building on this evidence, a greater understanding of patients' experiences will provide the insight needed to design future technology and increase the success of technologies when deployed in real-world contexts. By improving adherence to lifestyle changes, appropriately designed digital health technologies that apply this insight can ultimately help to prevent recurrence of cardiac conditions.

The analysis in this paper draws strongly on research in the field of Human-Computer (HCI). Our findings are analyzed from an HCI perspective, which emphasizes the benefits of iterative development of technology and user involvement throughout the design and evaluation process [20][21][22][23]. HCI approaches have been successfully applied to rehabilitation and self-management in other health domains [24][25][26][27]. Our decision to focus on both rehabilitation and self-management followed multiple discussions among the authors and cardiologists, which reflected the degree to which these issues are interconnected. The papers selected in this review have dealt with some of the common issues and challenges. An overview of these interventions, along with a synthesis of patients experiences can be beneficial to both medical and HCI researchers. To the best of our knowledge no previous systematic review has combined qualitative review methods and a HCI perspective to identify challenges and opportunities in the design of technology to support cardiac rehabilitation and self-management.

Objectives

The primary objective of this paper is to provide answers to the following research question: What are the primary barriers, facilitators, and trends of digital interventions to support cardiac rehabilitation and self-management? This question is answered by synthesising evidence from both medical and computer science literature. By taking a qualitative approach, we aim to engage more directly with people's needs from and experiences of technology that supports cardiac rehabilitation and self-management. Given strong evidence from the field of Human-Computer Interaction that user-centred and iterative design methods increase the success of digital health interventions, we also

assess the degree to which user-centred and iterative methods have been applied in the studies included in this review.

This review follows the Grounded Theory Literature Review (GTLR) method [28]. GTLR aims at producing new insights and enables researchers to develop concept-centric yet accurate reviews through a five-stage iterative process. The GTLR method adopts a rigorous search and selection process eventually invoking the Grounded Theory method for the analysis stage. GTLR recommends that initial research questions are identified at the outset of the review process, but also allows for a bottom-up iterative approach where new concepts are identified via a thorough and progressive analysis. Initial questions help focus the review during the selection and analysis stages but based on concepts identified during the analysis stage, it is acceptable for the final concepts to differ somewhat in focus from the initial questions. Following multiple rounds of discussion and refinement among the authors and cardiologists involved in this project the following initial research questions were identified:

1. What kind of technology support is provided for cardiac rehabilitation and self-management?
2. What design approaches were applied in designing the technologies identified?
3. What experiences and attitudes do patients have of technology?
4. What are the barriers of using technology for rehabilitation and self-management after a cardiac incident?
5. What are the facilitators for using technology for rehabilitation and self-management after a cardiac incident?

Methods

Overview

This review follows the five stages recommended in the GTLR method [28]: 1) identifying the key research questions, appropriate sources and search terms; 2) search for potential papers; 3) defined filtering for selection of papers and refining the sample for review; 4) a comparative and in-depth analysis of the papers through three coding levels; and 5) representing the emerging categories and concepts. In addition, we used the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) as guidance for conducting this review. The complete PRISMA checklist for this paper is included in Appendix 3.

In this section we describe the inclusion and exclusion criteria of our review, database sources and search keywords used, the screening and selection process, data extraction process and finally the analysis process.

Search strategy

In order to include a wide range of perspectives on designing technologies for rehabilitation and self-management of cardiac conditions, we selected papers from PsychInfo, Scopus, PubMed, and ACM Digital Library. HCI literature about designing technology for cardiac conditions was gathered from the ACM library. Similarly, psychology and medical literature on these kinds of technologies were gathered from PsycInfo and PubMed. Other major journals and conferences, to name a few of them,

Biomed central, IEEE, BMJ, International Journal of telemedicine and applications, SAGE, Global Telehealth, are included in Scopus.

Title, abstract and keyword search was carried out on the above mentioned databases to get the results for this review (see Multimedia Appendix 1 for search strings). Based on studies we were familiar with and to follow a structured process to define the keywords, we selected keywords to address three areas, namely, domain, technology and intervention that we considered most relevant to identify papers of interest (see Table 1). Domain keywords focused on CVD as the main field interest, together with related medical terms (e.g. Coronary artery). Technology keywords addressed diverse technologies used in inventions (e.g. mobile, sensors, telehealth). Intervention keywords reflect the different types of interventions addressing the field of cardiovascular disease (e.g. tracking, behavior change). It is important to note that our search strings include both MESH and non-MESH terms. This decision was made because the paper aimed at a broad exploration of research in both technology (e.g. HCI and software engineering) and medical disciplines. Technology databases included in our study (e.g. the ACM Digital Library) do not recognise MESH terms. Including both MESH and non-MESH terms represented the most balanced approach and helped to ensure consistency of search terms across the different databases.

We limited our search to papers published in the last 10 years, and focused on papers in the English language and including adult patients.

Table 1. Keywords used in the search terms

| Domain | Technology | Intervention |
|-----------------------------|-----------------------|---------------------------|
| Cardiovascular disease(CVD) | Mobile | Persuasive/persuasion |
| Cardiology | Wearable | Quantified self |
| Cardiac | Wearable sensors | Tracking |
| Heart disease | mHealth interventions | Behavior change/ behavior |
| Coronary heart disease | Smartphone | Personal informatics |
| Coronary artery disease | Tele-monitoring | Habit |
| Heart failure | Sensing system | Prevention |
| | Telehealth | Detection |
| | Telemedicine | Rehabilitation |
| | | Management |

Eligibility criteria

The review was concerned with the use of technology for self-management and rehabilitation practices in context to CVDs. This excluded several papers that would otherwise be featured in the review, such as those suggesting design concepts without evaluating them (e.g. [29][30]), those describing algorithms or software architectures to solve specific self-care problems (e.g. [31][32]), and those focusing on monitoring and detection techniques to support primary prevention of CVD (e.g. [33][34]). These types

of studies are very relevant to CVD in a broader sense, but as they do not provide evidence on the use of technology to support self-management or rehabilitation, they were excluded from the review. Papers included in this review involved an active role for patients living with cardiac conditions and technology that could be controlled by the patients rather than those in which patients have a more passive role. This meant excluding a number of technologies used only in clinical settings, and technologies based on biomarkers, photoplethysmogram, implantable devices and defibrillators. Excluding them enabled us to focus on the lived experience of people with CVD, rather than the clinical context of care.

Furthermore, this review focuses on papers with studies of patients with cardiac conditions. This excluded self- management and rehabilitation technologies focusing on other chronic conditions [19], wellness and lifestyle (e.g. [35][36]), or quantifying habits for health (e.g. [37][38]). By keeping the focus on cardiac conditions, the motivation for using the technology was to maintain cardiac health, not to pursue personal interest, leisure or general wellbeing, which would likely bring different principles for design and use. In order to attain subjective perspectives of patient’s needs and seek answers to our research questions, we focused on qualitative study methods for this review. Therefore, to be eligible for inclusion in this review, papers needed to include a technology intervention for cardiac management or rehabilitation, use qualitative study methods, and describe the use and evaluation of technology with users. Papers that did not follow the criteria were rejected. The full inclusion and exclusion table is shown below (see Table 2).

Table 2. Eligibility criteria

| | Inclusion | Exclusion |
|---------------------|---|--|
| <i>Domain</i> | Cardiac condition. | Other chronic conditions, General wellbeing and lifestyle. |
| <i>Technology</i> | Use of technology with evaluation; Technologies having active patient role, e.g.: Mobile, Wearable, mHealth, Telemedicine. | Design concepts, technology description, algorithms and software architecture without evaluation; Technologies having passive patient role: Biomarkers, Technology used in clinical settings, Photoplethysmogram, Implantable devices, Defibrillators. |
| <i>Intervention</i> | Secondary prevention involving self-management and rehabilitation. | Detection and monitoring for primary prevention. |

Screening and Data extraction

The search keywords retrieved 4282 articles, of which 3973 remained after removing duplicates. We first did a pre-screening of these papers by reading the title and abstract and removed papers concerning research abstracts, systematic reviews, protocols, workshops, studies dealing with patients under the age of 18, studies involving chemical and biological sciences as well as studies involving in clinical procedures. At this stage the first author (ST) reviewed all papers and the second author reviewed 10%. Where any

disagreement occurred the paper was not excluded at this stage. In the second phase of screening the first author reviewed the title and abstract of all remaining papers using the full eligibility checklist to decide if they should be included in pre-selection. This was done to exclude papers that involved studies inclining towards medical and clinical techniques, for example, studies related to biomarkers, photoplethysmogram, implantable devices and defibrillators, and studies related to algorithms, methods and techniques. The second author again reviewed 10% of the papers at this stage and agreement was verified across both authors. Where any disagreement was found, the paper in question was reviewed again by both authors and discussed to reach an agreement. Both the researchers then met and cross-checked 50% of the final pre-selection list, discussed inconsistencies and agreed upon a final list which included 61 papers for potential inclusion.

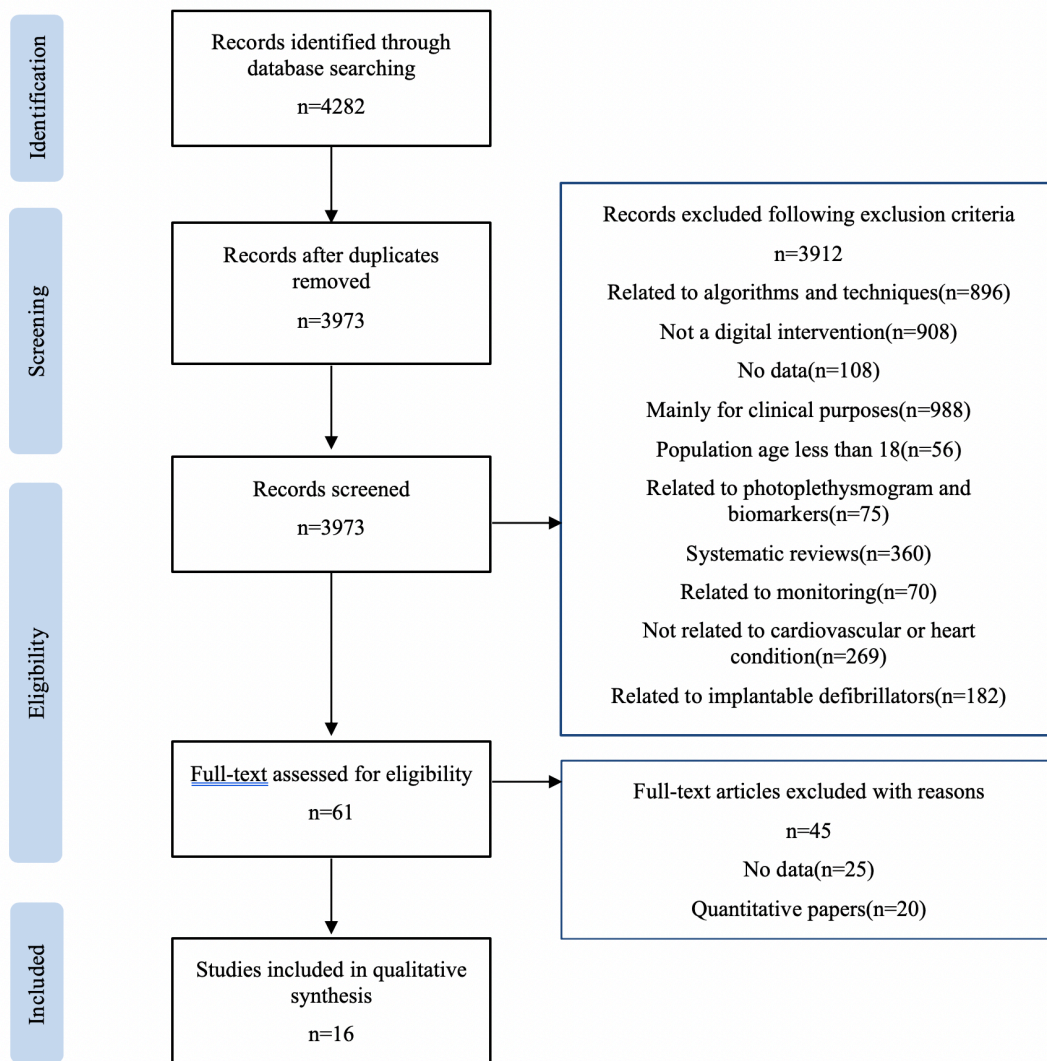


Figure 1: Flow diagram illustrating the screening and selection process of papers.

Each of these papers was further assessed in the final stage of the screening process to check if they applied qualitative methods and included qualitative data. Any paper that

contained both quantitative and qualitative data was included in the final review, but only qualitative data in these papers was analysed. 25 papers were found to include no data and 20 included only quantitative data. These papers were excluded. This left 16 papers that included qualitative data in our final analysis. Figure 1 provides an overview of the full screening process.

The Critical Appraisal Skills Program (CASP) checklist [39] was used to assess the quality of included studies and avoid the risk of bias. The CASP checklists are divided into three sections to assess internal validity, results, and relevance to practice of published papers and these sections are assessed by questions that can be answered with *yes*, *no*, or *can't tell*. Based on the number of questions scored *yes*, an overall rating of either *strong*, *moderate*, or *weak* was given to each study. The results of the assessment indicate that the majority of the papers included in the review are strong, while some were rated as moderate. Full details of the CASP assessment are included in Multimedia Appendix 2.

Data from the included papers was initially extracted based on the headings in Tables 1 and 2. This included data such as the participants numbers, study methods and settings for each study. In the final stage of data extraction the full findings and discussion sections of each of the 16 papers was extracted. This provided the data for our subsequent analysis.

Analysis and Synthesis

The analysis step of the GTLR method involves a comparative analysis process with three levels of coding: Open coding, Axial coding, and Selective coding. From the set of papers in the final review, ST selected a random paper and carefully read it again, highlighting key findings, which the GTLR method calls excerpts. Similarly, excerpts from each paper were then listed. At the axial coding stage these excerpts were articulated to form groups or insights. Both authors carried out an affinity mapping exercise on these excerpts. This led to the formation of groups and sub-groups of the excerpts. At the selective coding stage these groups were then compared and moved around followed by discussions among the authors to form themes. This process involved iterative back and forth analysis between the excerpts and groups identified, in which stages were repeated and papers re-read until a final consensus was reached. The coding process was supported by Boardthing [40], an online notice board software that allows individual and collaborative coding and analysis. The themes were repeatedly discussed and refined among the authors and the analysis was only complete as the final version of review documentation was ready.

Results

As noted above the keyword search retrieved 4282 articles, of which 16 were included in the final analysis.

Study Characteristics

Target users

All studies in the final list focus on patients who had gone through or were going through a cardiac condition. Some of the studies specifically target patients diagnosed with heart failure, myocardial infarction, and coronary heart disease. Furthermore, some studies

particularly involved participants post cardiac condition awareness and those who are in their cardiac rehabilitation phase. Some studies also involved physicians, informal caregivers, nurses and cardiologists as participants. The papers included studies of both cardiac rehabilitation [48][49][53][54] and self-management [52][46][56][41][44][51][42][47][50][45][43][55].

Different technology support provided

In general, the papers in this review investigated mobile or web apps, with some integrating sensors, to manage cardiac conditions. Papers featuring a web-based digital intervention included [41][42][56]. Some studies used mobile [45][48][49][50], tablet [51] and a combination of web and mobile systems [52][43][44][46][47][53] as digital interventions. Two studies did not involve any particular system. Instead they focused on patients' needs and perspectives of using an existing technology and potential of digital interventions for cardiac management [54][55].

Motivation of the studies

In general, support for self-management was provided through apps that aim to increase adherence, motivation and engagement. These could be achieved through gamification [48], by providing guidance and education about the condition [41][50][45][43][55], through reminders and notifications or by using patient data and sensor data to track and show their progress [52][49][55]. Many studies involved interventions to increase physical activity and exercise for cardiac patients [51][42][47][49]. Studies also aimed to facilitate better connection between patients and care-providers, nurses or health professionals by providing a medium to communicate and share data [46][56][45]. Two papers were about virtual and remote cardiac rehabilitation to enable rehabilitation for patients in rural and distant locations [53][49]. One paper focused on gathering needs and interests of CVD patients in order to effectively enable remote cardiac rehabilitation [54].

Table 1. Overview of the studies included in the final review

| Name | Participants | System | Research methodology | Findings |
|-------------------------------|---|--|--|--|
| Dithmer M. et al. (2016) [48] | Patients in a rehabilitation program diagnosed with heart failure, myocardial infarction, or angina pectoris. | “The heart game” is an application prototype developed for Android running tablets. It presents heart patients with a game like challenge every day and is designed to be played by a two-person team. It was designed to be used soon after discharge from the hospital and when the patient begins the rehabilitation process. | The prototype has been developed through a user-driven process and a triangulation of data collection techniques were applied. Evaluation was based on log files of application usage followed by qualitative interviews with 10 patients and 6 teammates. | Inclusion of a close relative or spouse in the game motivated the patients to perform rehabilitation activities. Gamification design principles engaged the users. |
| Yehle KS. et al. (2012) [52] | Patients with CHD and their informal caregivers from | Two food decision support systems, | Three focus group sessions with 20 CHD patients and 7 informal | Five themes emerged: Decreasing carbohydrate intake |

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| | cardiopulmonary rehabilitation clinic in Indiana, serving predominantly rural based population | Web based: Food for the Heart Mobile based: Mobile Magic Lens were developed to aid in daily dietary choices. | caregivers. During the focus group sessions, participants were asked about their favourite foods, dietary changes made since CHD diagnosis, challenges in making dietary changes, and ways of overcoming these challenges. Content analysis of qualitative data was performed to find themes through a grounded theory approach. | and portion size are common challenges; Clinician and social support makes dietary adherence easier; The systems could make meal planning and adherence less complicated; The systems helped save time and assist healthy choices; Additional features would be required to make tools more comprehensive. |
| Villalba E, et al. (2009) [46] | Participants were diagnosed with heart failure or should have suffered a cardiovascular accident, business managers and cardiologists. | CUORE is divided into three main areas: the user interaction system running on Microsoft's .NET framework, professional interaction through web-based portal, and common platform. The sensors and electronics to monitor patients in their daily routines include a blood pressure cuff, a weight scale, a ECG/HR monitor, and an oxygen saturation monitor. | A total of 26 people including 10 cardiac patients, 10 cardiologists and 6 business people were interviewed. The validation comprised two phases: first, the system was validated with patients; then, the system was validated with health professionals. | Some patients considered it would be a problem for them to integrate the system into their daily lives. Some felt that the app constantly reminded of their sickness. Most patients stated that being remotely monitored increased their feeling of security and comfort. Education on symptoms and medication was highly valued. Preference is given to continue using the devices they already own. |
| Jarvis-selinger S. et al. (2011) [56] | Participants included cardiac patients, physicians, nurses, and health professionals. | The study aimed at understanding how internet-based platforms could be used to support self-management and communication among patients, physicians, and health professionals. | Semi-structured interviews of a total of 48 participants over a period of 6 months was conducted. An iterative approach to data analysis was taken, employing a constant comparative method as a way to explore subjective experience. | Most important feature of the technology was considered to be sharing of patient health records. Majority of the health professionals felt that providing patients with accurate educational resources would be the best use of technology for self-management. Patients preferred face-to-face contact with doctors. |

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| Fischer S. et al. (2011) [41] | Participants were diagnosed with heart failure and attended the Manukau Super Clinic. | Web-based visualisations for educating patients and promoting behavioral change through interactive web graphics to visualise relationships between lifestyle, symptoms, patient parameters and the disease. | Usability of the application was tested using surveys. The effectiveness of the application was evaluated through semi-structured interviews with 18 participants. | The tool promoted knowledge and understanding of illness and associated symptoms thereby alleviating the distress and influencing self-management and behavior change. |
| Pfaeffli L. et al. (2012) [44] | Participants included patients diagnosed with CVDs and cardiac rehabilitation nurses. | Mobile SMS and brief video vignettes through participant website. | Intervention was developed with patient input using the following steps: conceptualization, formative research, pre-testing, and pilot testing. Interviews with 38 CR patients were conducted after the CR program. Interview analysis used thematic approach. | The mHealth format was considered to be particularly useful for patients who found it difficult to attend center based CR. Older participants viewed technology as a barrier due to unfamiliarity. |
| Katalinic O, et al. (2013) [51] | Participants included patients of stroke, paediatric palliative, brain injury and cardiac coaching. | Two home tele-health technologies (the Intel Health Guide and the Apple iPad) were trialled by four clinical services. The Intel Health Guide for cardiac coaching services and iPad for Paediatric Palliative Care, the stroke and Brain Injury rehabilitation services. | A total of 102 patients were involved in the study. Intel health guide and iPad was given to use for three months. Satisfaction surveys to assess the usability and usefulness of videoconferencing and home telehealth devices and clinical advantages of using technology. | Apart from technical issues like poor broadband and connectivity, Telehealth was found to play a useful role in improving access to services, especially for people who lived in rural areas. Both clinicians and patients readily accepted new technology, however usability and ease of use are crucial in ensuring acceptance of technology. |
| Antypas K. and Wangberg SC. (2014) [42] | Participants attending the CR program | Website based on open source content management framework Drupal. It consisted of profile page, activity calendar, a discussion forum, and general information about cardiac disease, training, symptoms. | Conducted a focus group with 11 participants of a cardiac rehabilitation program, 3 women and 8 men. Thematic analysis was used to identify and analyze transcribed data. | Seven themes were identified: Social; motivation; integration into everyday life; information; planning; monitoring and feedback; concerns and potential problems. |

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| | | Users receive feedback regarding their level of activity. | | |
| Geurts E. et al. (2016) [47] | This study involved patients with cardiac condition, a cardiologists and HCI experts for different stages of data collection. | The Back on Bike system consists of a mobile and browser based application that monitors cycling efforts of cardiac rehabilitating patients along with a dashboard for the medical staff. | Observations and contextual inquiries were held in the rehabilitation center with a physiotherapist. Followed by co-design workshop with four HCI experts and one cardiologist in training. 9 patients participated in a field study and results for four of the nine patients are described in detail in this paper. | The system reassured patients that they were cycling at the right heart rate zone. The system also encouraged healthy people accompanying the patients to adapt their pace to the patient's safe zone. The app reduced fear as it supported patients to cycle with others. Supportive messages and predefine routes motivated them to complete a tour. |
| Buys R. et al. (2016) [54] | Study patients were recruited from a supervised phase 2 ambulatory CR program, two community based phase 3 CR programs, and adult congenital heart disease clinic. | The study aimed at understanding current technology usage of CVD patients. Survey questions related to following technologies: mobile phone, internet, computer games, heart rate monitor, and physical activity monitor. | A technology usage questionnaire was completed by 310 patients. The questions were related to patient's characteristics, current technology usage, patient's interests and needs from a technology-based virtual cardiac rehabilitation intervention. Data analysis was conducted by SAS statistical software. | Patients were interested in CR support through mobile or internet. Patients reported interest in virtual-based and game based CR. Advice on exercise ideas, opportunities, diet, and stress received rating for including in technology. Technology should be designed for all ages including men and women. |
| Cornet VP. et al. (2017) [50] | Participants diagnosed with heart failure and their informal caregivers | Engage is a mHealth system designed for mobile or tablet devices to be use by patients or informal caregivers. | 15 participants used Engage for 30 days. Two usability studies, task-based and scenario-based generated a set of findings and design guidelines were proposed by triangulating the complementary results from task-based tests, scenario-based evaluation, and quantitative instruments. | Participants were concerned about adding a device on top of what they already have. Participants desired a simpler interface, there is a need to consider affective design and individual differences, in addition to technical usability and performance requirements. |

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| Banner D. et al. (2015) [53] | Participants were patients with acute coronary syndrome or following a revascularization. | The virtual CRP was designed to mimic a standard hospital-based CRP. It includes on-line intake forms, scheduled one-on-one chat sessions with the program nurse, case manager, exercise specialist and dietician, weekly education sessions, and data capture for the exercise stress test and blood test results. | 78 cardiac participants were enrolled in the study. Control group received routine care from their primary care provider and intervention group received an orientation to the vCRP. The program lasted four months in duration and a final semi-structured interview was undertaken with 22 participants. Evaluation included descriptive analysis of the data and thematic coding. | Five themes were identified: accessibility, making healthy choices, surveillance, barriers to participation, and perceptions of vCRP. Participants reported increased awareness and motivation to manage their health condition. Poor computer literacy was identified as a barrier. |
| Baek H. et al. (2018) [45] | User research was conducted on cardiac patients and doctors at a tertiary general university hospital located in the Seoul metropolitan area of South Korea. | A mHealth mobile phone application was designed using a mock-up tool. The app provides health information, health questionnaire, self-management, and dairy. | Three types of user research and user experience investigations including surveys and interviews with 35 patients, focus group interviews with doctors, and a usability test were conducted. Evaluation was carried out by analysing the opinions from doctors using card-sorting method and interview transcripts were analysed using constant comparative method. | Top three items that patients thought were important included exercise, dietary control, and weight management. The commonly required features were easy app use, up-to-date information on health, self-assessment, current health status and communication with doctors. |
| Salvi D. et al. (2018) [43] | Patients who had suffered a cardiac event were selected and analysed for suitability by physicians involved in the project. | The GEx (General exercise) system is composed of three main parts: the Mobile station, for monitoring physical exercise and providing live guidance during exercise sessions; the Patient station, which acts as a collector and gateway of patient's data and is responsible for delivering educational content to the user; and the Professional station, a | A randomised controlled trial was conducted with 118 participants to compare mobile-based rehabilitation, 55 patients versus standard care, 63 patients. User acceptance and perceived usefulness were measured with a questionnaire inspired by Technology Acceptance Model. | Educational level about heart related health improved more in the intervention group than the control. Exercise habits at 6 month follow-up also improved. |

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| | | web-based application used by doctors to prescribe and tailor each exercise programme, to visualise progress, and to be alerted in case of problems. | | |
| Beatty AL. et al. (2018)[49] | Patients from a cardiology clinic who were eligible for CR were the participants. | A mobile app was designed to be used as a tool for home CR and includes physical activity goal setting, logs for physical activity and health measures | A total of 13 participants completed the System Usability Scale, rated likelihood to use the mobile app, questionnaires on mobile app use, and participated in a semi-structured interview. | There was a desire for introductory training. Family and peer support were reported to influence mobile technology use. Participants desired ease of use and simplicity. |
| Smith R. et al. (2015) [55] | Cardiac patients, physicians and accredited social health activists. | Assessing the potential for using mHealth and mobile phone usage. | 15 participants were involved in semi-structured interviews over a period of 6 weeks. Evaluation involved thematic analysis of the interviews. | Challenges of CVD management were stated as poor patient disease knowledge, usability and lifestyle. Family support, knowledge support, health work and physician support is considered motivating. |

Design approaches used in the studies

Table 2 gives an overview of the design methods or guiding theories used in the studies. Overall, as all the papers in the final list are qualitative studies, most of the papers used surveys, interviews and usability tests and represented their evaluation and findings through themes (Table 2). Among these, some studies used theoretical frameworks of behavior change and user centered design approaches and methodologies. Examples included scenario-based tests, card sorting, goal directed design and persuasive design [46][56][44][42] [47] [50] [53] [45] [43]. One study used grounded theory to identify themes from participant responses [52]. Another study used gamification design principles to design the system with an aim to increase motivation and adherence to lifestyle changes [48]. One study assessed usability of technology using satisfaction surveys [51], another used a technology usage questionnaire to understand technology usage [54], and another used the system usability scale to assess the usefulness of a system [49].

The three main stages of HCI design process included in the ISO 9241 HCI development lifecycle are requirements gathering, producing design solutions, and evaluating the design against the requirements [57]. There is also a recommendation that this process is iterative, typically involving multiple cycles of design and evaluation. The design process, also known as the user-centred design, focuses on users and their needs in each stage of the process and iteration continues until it is fit for implementation. We found

limited evidence of studies applying a truly iterative approach and user-centred. 9 of the 16 papers stated that a user-centred design approach was followed, however it is not always clear that this involved multiple iterations of the design cycle [48][52][46][44][42][47][50][45][49]. Only 6 of the paper provided details of studies that involved users in each stage of the process [48][44][47][50][45][49]. 3 out of 16 studies involved users only in the final stage, i.e. evaluation [41][51][53].

Table 2. Overview of the theories and design approaches used in the final review

| Name | Design method / guiding theory | Users involvement |
|---|--|--|
| Dithmer M. et al. (2016) [48] | Gamification and gameful design principles (PERMA: Positive emotion, Relationships, Meaning, and Accomplishment) are used to design the application. Gamification principles like badges, levels and leader boards were used to increase engagement and motivation. | Requirements gathering Design/ Prototyping Evaluation/Validation |
| Yehle KS. et al. (2012) [52] | No particular design principles/ theory and design methodology mentioned. | Requirements gathering Evaluation/Validation |
| Villalba E. et al. (2009) [46] | Goal directed design methodology is applied. A three phase design process is used: conceptualization, implementation, and validation. | Requirements gathering Evaluation/Validation |
| Jarvis-selinger S. et al. (2011) [56] | Diffusion of innovation theory was used as the theoretical lens along with current telehealth literature for sensitizing concepts. Qualitative methodology, employing a constructivist approach. | Requirements gathering |
| Fischer S. et al. (2011) [41] | Used Common Sense Model of illness representation and showed visualization of body structure and behavior based on different symptoms through a web-based application. | Evaluation/Validation |
| Pfaeffli L. et al. (2012) [44] | A library of text and video messages were developed using self-efficacy theory framework and published exercise guidelines. | Requirements gathering Design/ Prototyping Evaluation/Validation |
| Katalinic O. et al. (2013) [51] | No particular design principles/ theory and design methodology mentioned. | Evaluation/Validation |
| Antypas K. and Wangberg SC. (2014) [42] | Different models of health behavior change are combined to form the tailoring algorithm. Tailoring is used as the theoretical framework. A methodological approach that is used to combine the user input and health behavior theory to develop a physical activity digital intervention for cardiac rehabilitation. | Requirements gathering Evaluation/Validation |
| Geurts E. et al. (2016) [47] | The prototype design was guided by three pillars: simplicity and ease of use, reduce fear and anxiety, and direct and indirect motivation. An HCI perspective is given by categorizing design decisions according to three pillars and show how these pillars resulted in concrete application features. | Requirements gathering Design/ Prototyping Evaluation/Validation |
| Buys R. et al. (2016) [54] | No particular design principles/ theory and design methodology mentioned. | Requirements gathering |
| Cornet VP. et al. (2017) [50] | Three frameworks guided the design process: SEIPS 2.0, Patient Work Lens for CHIT, and user-centered design. | Requirements gathering Design/ Prototyping Evaluation/Validation |

| | | |
|------------------------------|---|--|
| Banner D. et al. (2015) [53] | No particular design principles/ theory and design methodology mentioned. | Evaluation/Validation |
| Baek H. et al. (2018) [45] | No particular design principles/ theory and design methodology mentioned. | Requirements gathering Design/ Prototyping Evaluation/Validation |
| Salvi D. et al. (2018) [43] | Fogg's Persuasive Systems Design principles were used when designing the GEx system, health belief models were used to classify patients on the basis of the perceived benefits and barriers to self-efficacy in healthy behavior. The system design and development were guided by a combination of methodologies: Goal Directed Design (GDD), Persuasive Systems Design (PSD) and agile software development. "desired behaviors" were mapped into specific system's specifications, borrowing concepts from Fogg's Persuasive Systems Design principles. | Requirements gathering Evaluation/Validation |
| Beatty AL. et al. (2018)[49] | No particular design principles/ theory and design methodology mentioned. | Requirements gathering Design/ Prototyping Evaluation/Validation |
| Smith R. et al. (2015) [55] | No particular design principles/ theory and design methodology mentioned. | Requirements gathering |

User's perspectives of digital interventions for cardiac self-management and rehabilitation

This Section presents the final themes identified in our Ground Theory analysis.

Knowledge

Evidence from the review suggests that knowledge plays an important role in rehabilitation and self-management. Education and knowledge influences self-management and increases confidence. To explain this further, we have categorised knowledge into two types; background knowledge and personal and in the moment understanding.

General knowledge about CVD

General knowledge or background knowledge about CVD is the fundamental information or awareness that is required to be known by all CVDs patients. This can be information about one's health condition, symptoms, body, medication, preventive measures, and advised lifestyle changes. Background knowledge also includes awareness about different support systems that help people to care of themselves, for example rehabilitation support and digital interventions.

There is a growing trend to use digital interventions to provide the required educational support. A study conducted to validate a self-care digital system to manage cardiovascular condition at home emphasis that education on symptoms and medication was highly valued by patients and health professionals, however, younger patients had reservations about lifestyle education as they considered it to be intrusive and annoying. Similarly, patients who were initially be scared of new technologies were later, after introductory explanations, found it more easy to interact with the system [46]. Similarly, a study that evaluated the use of web-based visualisations of patient parameters for improving patients' understanding of their disease and increasing their level of control

over the rehabilitation process shows that enhanced knowledge and understanding of the illness and its symptoms can motivate protective action, such as, for the individual with heart failure to improve self-management of the illness and the symptoms [41]. For example:

"Now I understand why my legs always swelled up." [41]

"We truly know how to, what is happening inside his heart, and why he's getting all these symptoms. In the 2 years that we've been dealing with this illness, it's so good to have it summarised up so that we know how to care for ourselves better." [41]

Participants also repeatedly referred to the need to find the right answers either through an online forum or some kind of knowledge bank [42].

"It should be a forum where you have the opportunity to get the right answers, access to a resource, this is what I believe it becomes. It has an effect." [42]

Cardiac rehabilitation (CR) classes are also popularly known to provide the essential knowledge, guidance and support for patients.

"...Your class (cardiac rehabilitation) because they stressed what is really bad for you and what is good for you so that makes you stop and think when you are even buying your groceries to make sure you are getting the right stuff." [52]

Personal and in the moment understanding

Personal and in the moment understanding is the supplementary information patients seek to enhance their self-care process. This kind of information is acquired through personal tracking and monitoring and refers to the on-going knowledge people develop about their individual condition. Knowing one's body plays a key role in achieving control of the cardiac condition, however it may be hard to notice some changes and trends in everyday life. Technology has been used to make health and contextual information more easily available to patients and carers on an ongoing basis [58]. Patients state that being monitored by technology increases their feeling of security and comfort, by enabling a better ongoing understanding of their health [46]. Self-care technologies that used monitored data to guide people to exercise or train within recommended or safe zones boosted confidence and increased motivation.

"The application is not only beneficial for people who are afraid to exercise, but also supports people that have a higher risk to train too much." [47]

A study conducted to understand the current technology usage of CVD patients, and to understand their needs and interests found that ongoing advice on exercise ideas, exercise prompts, information on local exercise opportunities, healthy meal ideas and recipes and practical ideas to manage stress received the highest ratings for inclusion in a technology based CR platform [54].

"I am unsure if I am doing the right thing, like food, so I like advice on that" [55]

Social vs Individual

While most patients often manage their care autonomously, clinicians, other people living with the same condition and care-givers play an equally important part.

Individual responsibility

Responsibility for change in behavior is personal [42]. Changing behavior is easier if new habits are created by replacing old bad ones. To retain changes, it is important to make it part of the daily routine. Ubiquitous technology can support behavior change in the challenging situations of everyday life and remind users of their own commitments.

"If you could get a message every day, there and then?" [42]

"I believe that someone gets used to it, if we make a system, habits. That it doesn't get too much, that we know that...we go online...and we get our own responsibility of our own training" [42]

Technology can support small personal achievements like getting out of the house to get fit. Use of digital systems as a tool for self-management is valued especially among the younger ones.

"It gave me the opportunity to get out of the home and try and get myself fit after the operation. I believe it has achieved that and more. I feel better in myself and I can achieve most jobs without taking about it." [43]

Connecting with others

Patients often seek to connect with others living with the same condition and they use these interactions to understand how to live with their condition, validate their assumptions about their body and self-care, and to obtain emotional support [59]. Cardiac rehabilitation session is an excellent example of this kind of environment. A theme repeatedly expressed by the patients of cardiac rehabilitation program was the importance of not being alone in the rehabilitation and self-management process, this was an important factor that helped them during their visits to the rehabilitation center and it was something they wished to maintain after their discharge [42]. Additionally, cardiac rehabilitation attenders found great value in being able to ask nurses, cardiologists and dietitians questions according to their specific needs [44]. Digital interventions are also providing easy access to others with the same condition, health professionals and experts. A study on the experiences of patients undertaking virtual cardiac rehabilitation (vCRP) program demonstrated the potential of vCRP as a medium to provide easy access to healthcare professionals, nurses, exercise specialists and dieticians. Although there were some concerns about trust and privacy [42], many of the participants explained that having ongoing monitoring from healthcare providers, as well as support for self-management activities, helped them to adhere to their recommended program.

"You know I had stents four years ago, and you start off with the best of intentions, but nobody looks over your shoulder and you peter out. At this time, I felt this is a nifty program ... somebody's watching it and I better do it. Keeps you honest, keeps you focused" [53]

Keeping in touch with the group help to lift people's mood, is comforting and gives support, therefore many patients liked to use forums and online groups. Groups and forums on the internet are seen to help individuals be more committed to fitness by sharing goal completions and brag about it for healthy competition. Forums brought more focus and motivation as it makes individuals feel obliged to do activities. A study that used gamification for telerehabilitation program of CVD patients also demonstrates the

importance of social and family support, with patients stating that the most important aspect of the game was being able to play with a partner, thus enabling them to deal with rehabilitation as a team.

"Training diary on the Internet...And also have a group where someone can subscribe to a forum, or have a...to brag...yesterday I walked for an hour and today I have been to the training...and tomorrow I have thought, yes...So, it is like this that someone gets to, a bit, a bit like a competition, internally between each of us. We will train, as much as possible we will commit to ourselves a bit more also." [42]

"I am saying that if we have it fixed, one time per week, that we send a message to each other and then, then you feel committed to say yes, for as long as you like... Yes, then you must have something else that really, you have something else that you have to do, or else...you just do it." [42]

Motivation and Demotivation

The systems in the listed papers took a number of approaches to provide engagement and motivation towards self-management. Some of the key features of technology and patient's attitudes towards them are described below.

Feedbacks and reminders

Digital health interventions like text messages, mobile and web application reminders pushes patients to maintain the desired changes [44]. Applications using gamification principles are considered motivating as they allowed score, activity and goal comparison, healthy challenges and competitions. Creating small manageable tasks was positively received by heart patients. Applications use data visualizations to show meaningful comparisons to see how well they progressed [48].

"I went cycling without the application today, but it was less fun!" [47]

Two teams explicitly stated that on a day with bad weather, they would not have gone for a walk had they not been motivated by the application [48]

Reminders in any form were positively accepted by patients. Text messages even though intrusive pushed them to do exercises and many stated that reminder like an alarm is needed for medication management [46]. On the other hand, some patients did not like, reminders as it constantly reminded them of their sickness

Tracking and monitoring

Digital health interventions that had the ability to track patient's activities, heart-rate and current health status and showed their progress over time was considered to be valuable and engaging [47]. In the study to understand the current technology usage of CVD patients, 68% patients reported to find heart rate monitoring important when exercising at home [54]. In addition, patients also anticipated that they would be able to manage their disease more efficiently if their daily data could be easily entered in an app and shared with their doctors [45].

"I like the fact that I can put all of that and track it, and that my doctors can as well. I can show my doctor what I've been working on." [49]

"I think that the idea of an app that records all of the information that this app is doing will be very valuable. Actually somewhat of a motivation for me to do this thing." [49]

Personalization

Some studies in this review suggested that digital interventions that gave the ability to the user to personalize the application based on personal interests contributed towards motivation [47] [42]. For example, one of the patients in a study that evaluated patient's motivation when using a mobile application that guided them while cycling, suggested the app would be more engaging and fun if it had the flexibility to insert his preferred routes along with the preloaded ones. However, another patient in the same study preferred the pre-defined routes [47]. Another study showed that while patients preferred simple interaction methods, they also asked for the possibility to apply advanced settings [54]. The findings of the same study also suggested that future of technology enabled CR might include different solutions to reach both men and women in order to better engage a broader target population of CVD patients [54].

Increased burden

Some studies in this review demonstrated patient's concerns in using technology. For instance, some patients suggested that adding a device on top of what they already have led to them getting side tracked and thus not using it every day [50]. Patients in the older age group were especially resistant to use technology, some of them lacked interest and found it burdensome.

"I'm retired and I gave all the computerization that I wanted up, that is it I do not even look at it and I will not even turn it on." [56]

Furthermore, lack of time and other priorities is a barrier to self-management and use of technology. Most patients already have measuring devices at home, such as weight scales, blood pressure cuffs and preferred to continue using devices they already know [46].

"There are people who like this(application) kind of stuff... and got the time. So for these people it might be great." [50]

Acceptability of technology

On the contrary, studies in this review also demonstrated patients' willingness to use technology. For example, one study reported patient's interest or intent to use application for CVD management was high, despite the fact that most were seniors who were unfamiliar with the information technology environment [45]. Overall, in most studies, patients as well as clinicians readily accepted and showed interest in learning about new technology [45] [51].

Nevertheless, in order to reach the entire target population of CVD patients, a variety of technology solutions should be designed to reach both men and women [54].

Usability

Finally, usability and ease of use is crucial for acceptance of any type of digital intervention and thereby influences engagement. Many studies in this review emphasise that simple interaction methods are preferable. For example, on study stated that 38% of the patients prefer an interaction of no more than a few mouse clicks [54]. Patients unfamiliar with technology positively stated that it was just a matter of getting accustomed and if they learned and used the app regularly, they would find it simple. Some patients also suggested to consider e-literacy issues and initial training [42].

“It was pretty easy...I like that it’s simple.” [49]

“I’m not used to this. Once I get used to it, I’ll know where everything is.” [49]

Discussion

Principal Findings

This review aimed to understand user’s perspectives of technology in cardiac rehabilitation and self-management and identify barriers and facilitators of the use of technology. Results suggest that many patients have a positive attitude towards the use of technology. The grounded theory approach enabled us to identify common themes across the included papers, resulting in three principal findings:

1. Designers of new technologies and clinicians recommending existing systems to patients should consider seek to support both background knowledge and greater in the moment understanding. Background knowledge and awareness about the condition, its symptoms, medication, and post-hospital care measures is an important factor for effective self-management. But effective self-management also requires patients to be aware of their current body condition and changes in their body, providing reassurance and enabling them to take appropriate measures in self-management.
2. Self-care is a personal responsibility and people like to try different ways to keep themselves motivated to continue performing self-management activities. For some, but not all, opportunities to stay connected with family, caregivers, and others with similar health condition is considered as one of the most effective ways to stay motivated and driven towards rehabilitation activities. Again, technology that supports both approaches is likely to be most beneficial.
3. Technologies can use different approaches to support engagement and motivation towards rehabilitation and self-management, including personalization, tracking and monitoring, reminders, and feedbacks. However, they should take account of the potential to demotivate due to issues including overburdening caused by different devices and applications, privacy concerns, lack of trust, lack of interest, and system usability. If not properly accounted for, these issues can impact the acceptability of systems and become major hinderances to effective rehabilitation and self-management.

These key findings are discussed in greater detail below and also considered via the lens of relevant HCI literature.

Our first principal finding emphasizes this importance of different types of knowledge. Awareness of available resources, for example, awareness of rehabilitation classes, existing online support groups, existing self-care digital applications and remote rehabilitation videos and programs is important so that patients can leverage these resources for better and sustained recovery and smoother transition to long term self-management. Additionally, ensuring patients have knowledge of available emotional and physical support helps to foster self-efficacy if they feel overwhelmed by their CVD condition leading to the inability to effectivity self-manage [60]. Prior work in HCI has also identified knowledge as an important factor influencing self-care. For example, a

study exploring patients' transition from hospitalization to self-management emphasizes gaps in knowledge, resources, and self-efficacy after discharge and demonstrates an interconnection between them [60]. The study describes knowledge as information provided to patients about their condition, medication, and management; resources as social and physical, e.g., caregivers, access to health services, etc. Self-efficacy is described as the patient's confidence in their ability to self-manage their condition. The gaps highlighted in that study are consistent key findings of this review. The authors recommend that at a system or hospital level, emphasis on verbal communication of information should be avoided. Ubiquitous computing and embedded technologies could be utilized to capture and retain verbal information received during hospitalization. In addition, hospitals should provide support and trusted sources of information for patients' access to expertise. Based on our findings, these recommendations are also clearly applicable to cardiac rehabilitation. Similarly, work in HCI describes how patient's understanding of their illness and availability of social and physical resource mediates their self-efficacy [61]. In contrast with prior work, our study has also highlighted the importance of supporting in the moment knowledge, which can be acquired through tracking and monitoring. It appears that both types of knowledge can be an integral part of effective cardiac rehabilitation and self-management.

Effective self-management requires patients to change certain behaviors. An individual's inclination to change behavior depends on the extent to which s/he is motivated to change [62][63]. Our findings highlight that motivation for action is driven by both individual factors - such as, personal responsibility, emotions, and goals - and also by external influences - such as, friends, family, care givers, health professionals, and personalized and persuasive features of technology. These findings reflect on Deci and Ryan's Self-Determination Theory (SDT) of motivation, which states that human's optimal move towards growth is driven by three needs; Autonomy - the need to have control over one's behavior, Relatedness - the need to interact or be connected to others; and Competence - the need to experience positive effects of one's activity [62]. Previous HCI research [24] [64] provides helpful guidance on how technologies can support these basic needs and also highlights design related tensions that can arise in balancing different needs. For example. Nunes et al. [24] highlights tensions in the degree of autonomy to be provided to patients, noting that technologies should take into consideration the different levels of autonomy given to the patients for self-care, as it is highly dependent of the disease and the patient's current condition. Although patients are in charge of their health condition, it is important to reflect on the stages or decisions where a clinician's support is needed. Treatment of CVD relies on a combination of medication and lifestyle changes and there exists an individual difference in the disease management process. Individual differences refers to how people are similar or different in their ways of thinking, feeling, and behaving[65], this would include patient demographics, situational or contextual changes and environment. The Transtheoretical Model of Behavior Change[66] suggests that effective behavior change could be obtained if personalized feedback with different motivational levels or at different stages of the behavior change process is provided to people. Therefore, it is important to take these differences into account and leverage technology to provide tailored care. In the case of healthcare technologies, the one-size-fits-all approach could hamper effective self-care practices [67][68]. Nunes et al. also stresses on integrating self-care technologies in everyday lives by prioritizing lived

experiences of patients [24]. This is also emphasized in Rooksby et al.'s discussion of "lived informatics" and "design for interweaving"[69]. In other words, in order for the healthcare technologies to be successfully integrated in an individual's life it is necessary to acknowledge the everyday life of the individual [5]. Moreover, results of this review demonstrate that patient's adherence to self-management through healthcare technologies can be improved if technology does not act as a burden in their daily life and is easy to use.

Digital health interventions draw on two central domains of study, those originating in health (e.g. medicine, biomedical sciences and psychology) and in technology disciplines (e.g. computer science, HCI and software engineering). This trend is seen in the papers listed in this review. Blandford et al. [70] highlight seven areas of contrast in practice between technical and health research. They emphasize that skipping over stages of iterative design prior to investing in large-scale evaluation of digital health technology leads to sub-optimally designed solutions. In the HCI community, there is a growing practice of involving end users early on in the design stage and then throughout the full design and evaluation process. In contrast, the studies listed in this review show a limited evidence of applying user-centred and iterative design processes. Blandford et al. [70] also suggests that failing to learn how the nuances of design affect user interaction and engagement leads to failure in replicating it in different contexts and propagates risk from one design to another. Future research on technology to support CVD should address these limitations. Involving relevant users, in this case patients, caregivers, and health professionals in each stage of the design process will help reduce user experience challenges and increase acceptance leading to more effective digital health interventions. Core to addressing this limitation is appropriate and focused engagement with key patient groups. In this context, while CVD impacts adults across all age groups, it is important to also recognize that CVD and other chronic illnesses are particularly prominent among older populations, their distinct challenges and complex needs bring important implications for the design of such systems [71]. The effectiveness of user-centred design with older adults can be seen in the increasing number of studies involving older population in the early design stages [72][73].

Limitations

As the aim of this review was to investigate and get subjective evidence of the barriers and facilitators of using technology for cardiac rehabilitation and self-management, only qualitative papers were considered and review is limited by the analysis of the studies included. The possibility in subjectivity in analyzing the findings is acknowledged, although strategies to limit bias were undertaken through the process of grounded theory analysis and consultation with second reviewer. Additionally, the included studies were of varied sample sizes and the technology was used for different amounts of time in different studies. We acknowledge that this variation could have had an impact on the themes emerging in this review.

Reflective Statement by Authors

This research took place in the Republic of Ireland. It is part of the Eastern Corridor Medical Engineering (ECME) collaborative research project which seeks to improve cardiovascular health with a broad focus on enhancing user ready sensor technology, improving smart wearables, reducing the complexity of point of care diagnostics and

improved smart, clinically relevant monitoring in the AAL and rehabilitation environments. ECME is a partnership between five academic research centres in Northern Ireland, the Republic of Ireland and Scotland, and the Southern Health & Social Care Trust. It involves collaboration between researchers in medical and technology fields. Both the authors of this paper are based in Insight Centre for Data Analytics at Dublin when this study was conducted. ST was raised in India and had lived in Dublin for two years at the time of the study. She has experience in UX design in mobile and assistive technologies. DC has multigenerational roots in Ireland and is an expert in the field of Human Computer Interaction with a focus on the design of digital health technologies. Neither author have direct lived experience of CVD. This paper did not seek to directly address issues such as ethnicity, social and cultural background, and gender and standard checklists, including the Critical Appraisal Skills Programme (CASP) tool, were used to assess the quality of included studies. However, we recognise the potential for bias, both in own analysis and in the original research papers.

Conclusions

The primary objective of this review was to applied qualitative methods to answer the following research question: What are the primary barriers, facilitators, and trends of digital interventions to support cardiac rehabilitation and self-management? Our findings show that the use of technology is acceptable to many people undergoing cardiac rehabilitation and self-management. While background knowledge is an important facilitator, technology should also support greater ongoing and in the moment understanding. Connectedness is valuable, but to avoid becoming a barrier technology must also respect and enable individual responsibility. Personalisation and gamification can also act as facilitators to engagement, but care must be taken to avoid overburdening people. Findings also highlighted limited use of iterative, user-centred approaches to guide design in this space. Going forward, further application of user-centred and iterative methods represents a significant opportunity.

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Abbreviations

HCI: Human-Computer Interaction

CVDs: Cardiovascular Diseases

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