Perspectives on Contextual Information in Dutch Cardiac Rehab: Implications for Holistic Telemonitoring

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Abstract. Cardiac telerehabilitation (CTR) relies heavily on telemonitoring, predominantly gathering automated biophysical or survey data for clinical decision-making. However, lifestyle change during and after cardiac rehabilitation (CR) outside hospitals is impacted by many contextual factors, including mental well-being or social support. Failure to acknowledge these factors in remote cardiac care could result in healthcare professionals (HCPs) offering standardized recommendations that hinder health management. To gain insights into the utilization of contextual information in clinical decision-making in Dutch CR, we conducted semi-structured interviews with seven HCPs and CR experts. Our data analysis highlights the importance of routine, physical, and psychosocial information during holistic clinical decision-making. We argue for a transition towards a holistic approach to telemonitoring in CTR, discussing implications for more inclusive and contextual data-gathering practices.

Keywords: cardiac rehabilitation · contextual information · holistic care · telemonitoring · qualitative study

1 Introduction

Cardiovascular disease (CVD) ranks among Europe's top mortality causes [101]. Lifestyle interventions, like *cardiac rehabilitation* (CR), significantly enhance CVD prognosis by targeting the improvements of behavioral risk factors such as insufficient physical activity, unhealthy dietary habits, prolonged stress, and smoking [88,101]. Post-COVID-19, cardiac telerehabilitation (CTR) is gaining traction globally, notably in the Netherlands [25,79]. By leveraging communication and telemonitoring technologies (e.g., mobile and sensor-based devices), CTR facilitates *the transmission of information* between patients who undergo

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the CR program in the home environment and healthcare professionals (HCPs) who use that information to check lifestyle advice adherence and provide feedback and recommendations [43]. Nonetheless, the required monitoring information related to CR-targeted behaviors varies across systems and lacks a clear definition in human-computer interaction (HCI) research. Patients typically adhere to clinical recommendations independently, tracking data such as physical activity levels, consumed foods, and stress levels via self-reported surveys or wearable sensors for HCPs to use as metrics in their clinical decision-making process [27,63,97]. However, changing one's behavior *outside the controlled hospital environment* can be influenced by many *personal, contextual factors*, such as work, family, and morale, currently not captured by telemonitoring technologies [44,59]. Although *holistic care* principles are implemented in co-located CR, enabling HCPs to gather comprehensive insights into the physical, mental, spiritual, and contextual aspects of the patient's experience, thereby facilitating personalized rehabilitation approaches [99], this is rarely the case in CTR. Despite telemonitoring's pervasive role in remote cardiac care and the patient's everyday life [55], its design often prioritizes gathering behavior-descriptive data (e.g., step count, sleep quality score), neglecting the patient's situational and experiential context.

Recent research in HCI demonstrates the value of juxtaposing wearable sensor data with patient-generated contextual information, such as motivation and personal experiences with lifestyle change, for clinical decision-making [95]. Failing to monitor a patient's ever-changing context alongside quantified behaviors can lead to the depersonalization of behavior data, rendering it unactionable for HCPs [95]. This can result in standardized recommendations for patients in remote environments, potentially hindering long-term health outcomes [11,94]. Although the need for combining objective behavior data with contextual insight in health tracking has been expressed [2,19,95], there is a lack of investigations into *what types of patient contextual information is relevant, and how it is utilized by CR HCPs in lifestyle coaching and counseling* as a first step towards more inclusive CTR telemonitoring practices. To address this gap, we explore multidisciplinary perspectives on using contextual information in CR practices. We engage with seven HCPs and CR specialists in the Netherlands area, where the adoption of telemonitoring in remote care is of growing interest [55]. We find that HCPs prioritize a deep understanding of the situational circumstances of behaviors like motivation and routines over detailed behavior descriptions such as physical activity or stress levels. We identify the composition of *contextual information* needed in CR and its use in clinical decision-making, propose an alternative holistic approach to telemonitoring, and discuss implications for the future design and development of telemonitoring technologies in CTR.

2 Background and Motivation

2.1 Multidisciplinary CR Teams, Holistic Care and Contextual Information

The Multidisciplinary Efforts in CR. Cardiac rehabilitation (CR) is considered essential for long-term recovery and patient management [32], addressing the crucial CVD risk factor: unhealthy lifestyle [77,85]. CR, a complex model of care, involves multidisciplinary teams of CR-trained HCPs, including *nurses, dietitians, physiotherapists, cardiologists, psychologists, and sports physicians* [93]. As a main part of CR programs, HCPs conduct educational and training sessions addressing healthy behaviors (also called "core components") like physical activity, diet, emotional recovery, and coping [50]. Each professional is assigned a distinct core rehabilitation component [34], or assumes the overall responsibility of overseeing the patient's rehabilitation trajectory [93]. The nurse typically acts as the case manager, offering ongoing phone consultations and addressing patient queries, while physicians and psychologists provide periodic consultations or address issues as flagged by the nurse. The HCP network engages in collaborative assessment of behavioral factors and patient adherence to recommendations, coordinating care to address various aspects of patient well-being [10]. Following program reassessment, HCPs guide individual self-management [16], emphasizing the implementation and maintenance of healthy behaviors at home [32,88].

Holistic Care Principles in CR. From a patient's perspective, being diagnosed with a heart condition and facing significant interventions, along with a flood of information and lifestyle changes, can be profoundly challenging. This process is much more complex than merely following recommendations on exercise and healthy eating [67,94]. By embracing *holistic care principles*, HCPs collaborate to provide goal-oriented care tailored to the patient's needs *beyond illness* by looking at the patient as a whole, specifically, as the unity of *body, mind, spirit, and surrounding systems* [99]. In co-located CR, HCPs gather patient information on core components, adapting goals based on individual insights for improved outcomes [10,66,93]. For instance, family narratives are documented next to the objective assessment of physical improvements for goal and advice adaptation [50,69]. Nonetheless, the type of information these narratives contain and the strategies HCPs use to obtain information contextualizing healthy behaviors from patients are unknown. Although plenty of clinical studies investigate patients' experiences with CR programs [29,31,41] and barriers and facilitators of patient participation [1,58], adherence [35,68], completion [73], and self-management post-program [22,83], these insights are mainly used to suggest improvements of CR procedures. They are not discussed in the context of clinical decision-making. Armed with the knowledge that utilizing insights into patient barriers, facilitators, and overall context in clinical decisions during CR significantly correlates with shortened recovery time post-cardiac event [54,59], we aim to outline initial categories of contextual information used in clinical decision-making in CR from the perspective of a multidisciplinary group of HCPs. These

insights may inform the development of a CTR system that integrates comprehensive principles from co-located CR practices.

2.2 Telemonitoring Practices and Data Needs in C(T)R.

Current Telemonitoring in Remote Cardiac Care. Cardiac telerehabilitation (CTR) technologies emerge as solutions to enhance CR participation by overcoming barriers such as program awareness, transportation issues, and low social support, compounded by increased risk factors post-in-clinic phase [12,63,64,103]. CTR often employs telemonitoring (e.g., wearable sensors or self-reporting automated surveys) and communication tools (e.g., texting, videoconferencing) for patient-clinician information and feedback exchange to ensure adherence to lifestyle recommendations [17,56]. After analyzing recent systematic reviews of CTR systems, we have found a consistent trend: this exchange heavily relies on quantifying core CR components (i.e., behaviors), particularly physical activity [17,43,49,56,61,65,71,84]. For instance, Zhang et al. [105] utilize a wearable activity tracker to monitor physical activity levels (i.e., through acceleration and steps) between hospitalization and CR, providing data for nurses to offer online feedback. Similarly, Herkert et al. [52] track exercise progress through in-app surveys and activity sensors, measuring post-session exertion and daily activities. Although less common, other telemonitoring systems extend beyond physical activity, including self-reporting cigarette consumption via in-app surveys, uploading meal images, logging weight changes, self-evaluating sleep quality, and measuring sleep efficiency with wearable sensors [18,28,37,46,80,92,100]. While a detailed examination of data collected by CTR systems warrants further investigation, our focus lies elsewhere. Instead, we highlight the prevailing emphasis on *quantifying behavior* in current CR lifestyle telemonitoring and the oversight of *contextual information* like perceived self-efficacy, habits, and family obligations crucial for understanding human behavior in home settings [73]. Notably, while evaluating their CTR system, Herkert et al. [52] highlight the inability to proactively prevent decreased exercise adherence due to the lack of information on patients' physical complaints and motivators. As telemonitoring advances, designers must acknowledge the challenge of expecting *diverse patients with various circumstances* to conform to standardized feedback solely based on biophysical data and automated surveys [94]. Recent HCI research underscores the importance of individualized design for cardiac technologies [33,94], as neglecting this may lead to misalignment with the patient's "normality" [96], poor engagement, adherence, and effectiveness in behavior change [51].

Data Requirements in Telerehabilitation. Due to the intricate network of HCPs and complex targeted behavioral components, defining data requirements for lifestyle monitoring in CTR is challenging. Examples of collected data vary from system to system. In exercise-based CTR, Shimbo et al. [70] suggest measuring activity intensity parameters and participant condition indicators in exercise. In a comprehensive CTR portal, Goevaerts et al. [46] classify self-reported

data such as physical activity, sedentary behavior, alcohol, nutrition intake, and stress to detect and assess risk behaviors. Nonetheless, within recent HCI and Computer-Supported Cooperative Work (CSCW) research, there is a suggestion that the data needs of HCPs in CTR are more intricate than what current systems provide. In a study on telemonitored data supporting CR, Tadas et al. [95] highlight the concept of "situated objectivity", which integrates standardized, automated data with contextual understanding [78]. They emphasize the importance of periodically sampling personal experiences alongside objective data like physical activity levels to contextualize them effectively. The transition from *data* to *information* can assist HCPs in understanding patients' challenges in meeting recommended targets. These conclusions find support in other telemonitoring interventions. Caldeira et al. [26] highlight HCPs' reliance on patients' subjective input for interpreting telemonitored data in stroke telerehabilitation. Similarly, Amorim et al. [3] note the need for patient subjective input in HCPs' decision-making for musculoskeletal conditions telerehabilitation. Andersen et al. [4] emphasize the importance of the patient's own data interpretation in collaborative ICD data analysis. Akinsiku et al. [2] stress the significance of telemonitoring information tied to the patient's context in stroke physical rehabilitation, categorizing it into areas like motivation, mental health, and caregiver assessment. There is a lack of similar studies delineating the contextual information needed in CTR; we expand on existing work and define similar information categories within CR. While Akinsiku et al. [2] term this information "experiential", we will use the term "contextual information". This distinction arises from the differing focus between stroke and cardiac rehabilitation; the latter involves a more complex recovery process, with patients undertaking long-term behavioral changes influenced by various contextual everyday life factors extending beyond mere task execution.

3 Study Design and Method

Acknowledging that behavior-descriptive data gathered in CTR is not enough for holistic clinical decision-making, we aim to understand *what types of patient contextual information is relevant, and how it is utilized by CR HCPs in lifestyle coaching and counseling* as a first step towards holistic telemonitoring.

Participant recruitment was done through snowball sampling from a teaching hospital in the Netherlands, a CR center in North Belgium (Noord Brabant area), and two Universities in the Netherlands. CR programs in North Belgium are very similar to the Dutch programs. We selected at least one participant for each CR behavioral component (2 psychologists – CP1 and CP2, one dietitian – DT, one physiotherapist – PT, one sports physician – SP) and two CR experts (one project manager – PM, one specialized nurse practitioner – NP) (Appendix A.2).[1] We conducted individual semi-structured interviews, lasting 45 to 90 min each. Four interviews were in person, while three were held online via Microsoft

[1] In this paper, participants to this study are also referred to as 'HCPs' or 'clinicians'.

Teams due to COVID-19. All interviews were audio recorded, with online ones also video recorded with participants' consent.

Before the study, an interview guide and a visual Miro board were developed to guide the conversation. The board contained patient barriers and facilitators of attendance, adherence, and completion of CR identified from a representative corpus of literature (Appendix A.1). After being introduced to the context and aim of the research, participants were given 10 min to review the Miro board. Questions addressed the types of information related to the patient's context participants use in lifestyle coaching and counseling, methods of collecting such information, and their link to addressing CR-targeted behaviors. Participants used the Miro board to define categories of information starting from the collection on the board. Recordings were transcribed verbatim. Semantic and descriptive thematic analysis was employed to identify recurring themes containing contextual information [30]. Transcriptions were segmented into distinct meaning units related to contextual factors (e.g., work and routines), each assigned a consecutive code to maintain context [40]. These meaning units and Miro visualizations were used to identify recurring themes representing broader categories of contextual information (e.g., everyday normality).

4 Results

4.1 Various and Subjective Ways of Collecting Contextual Information

Our findings emphasize the crucial role of *patient contextual information* in clinical decision-making within CR, essential for understanding patients and guiding their rehabilitation journey. HCPs rely on personal and situational context to grasp the reasons behind patient behaviors. While lifestyle behavior data (e.g., self-reported physical activity levels, physiotherapy session metrics, self-reported smoking habits) is a starting point, contextual insights (e.g., busy family life) help elucidate underlying reasons for why patients behave in a certain way. HCPs follow *holistic care* principles, interviewing patients and asking open-ended questions. During intake appointments, case managers collect comprehensive information on patients' well-being and surrounding systems. Other HCPs might use issues with adherence (e.g., low physical activity) as triggers for delving further into a patient's personal situation. The information is recorded in the patient's medical file and becomes available to the rest of the multidisciplinary team. Important contextual information for CR coaching includes details about the patient's *everyday normality, social environment, psychological and physical well-being*, and *ability to leverage knowledge*.

Participants come from different expertise and specializations, each an important puzzle piece during CR. We observe different approaches in which they extract and document contextual information based on the different degrees of closeness with the patient, as well as with administrative versus clinical perspectives. For instance, the nurse practitioner (NP) has the most personal relationship with the patients and views them as a complex ecosystem of factors, not as

a clinical subject defined by one's condition. They use the intake appointment at the beginning of CR as an essential opportunity to establish a comprehensive patient profile. Subsequently, during consultations or therapy sessions (e.g., psychotherapy or physiotherapy), all HCPs try to get to know the patient personally to gain trust and adapt their advice to the individual. However, there are friction points regarding how holistic these consultations are since the level of intimacy of the conversation, even though deemed important, is not standardized. For instance, the project manager (PM) argues that the textbook procedure of CR intake appointments is not personal enough: *"it's [the intake appointment] not really focused on the more difficult things to grasp - like their needs, wishes, past experiences, and expectations. [...] I think it's really important to really understand the patient more than just the numbers that are attached to them - my age is 59, my weight is 120 kg and my physical activity behavior is low"*. All our participants, however, unanimously agree that CR is a personalized journey shaped by the patient's unique circumstances. Specialists, for instance, employ subjective interpretation and professional intuition to navigate the complexities of personal situations, stratifying patients into appropriate treatment strategies. The psychologist (CP2) assists patients with minimal social support and mood disorders such as anxiety or depression. The sports physician (SP) identifies physical restrictions based on the patient's well-being and explores personal exercise possibilities by targeting trainable aspects according to daily routines, physical capabilities, and mental well-being. Conversely, the dietitian (DT) might try to understand the patient according to a structured procedure, beginning with background factors such as lifestyle and comorbidities, then inquiring into personal factors like social support and confidence, and ultimately focusing on existing dietary knowledge and beliefs regarding illness and treatment.

Although of different types, the entanglement among the contextual information HCPs use for clinical decision-making is significant. For instance, a patient's *social framework and support* directly influence their *routines and obligations* in the home environment, while their *comorbidities and physical limitations* can negatively affect their *motivation and health beliefs*. Similarly, *depression and anxiety* can limit a patient's *ability to leverage CR knowledge* about healthy behaviors in their everyday life. HCPs use entanglements and dependencies to extract the right contextual information and identify root problems in a patient's rehabilitation to provide personalized strategies. At the same time, we observe that behavioral data can become contextual information when identifying issues with other behaviors. For instance, data about physical activity levels is utilized as context for dietary problems, whereas information on the patient's smoking behavior can be used to contextualize a decline in exercise capacity.

4.2 Contextual Information About the Everyday Normality

Creating an initial profile based on the patient's *everyday normality* is essential for pinpointing practical barriers and customizing the care pathway accordingly. This information is regularly updated with follow-up questions throughout CR to assess how patients are adjusting their normality to rehabilitation goals and

whether these goals align with their habitual lives. By gathering this data, HCPs aim to establish a personal connection with the patient, fostering trust and gaining insights into their individual needs. NP exemplifies: *"I always ask: 'what kind of work did you do before?' just to get to know them. I do not identify the patient because of a heart attack – it could happen to anyone – but because I know which patient I'm talking to"*.

Existing Lifestyle, Work, Routines, and Obligations. Before initiating any lifestyle changes, the patient's existing lifestyle is evaluated using standardized questionnaires like the International Physical Activity Questionnaire [98] supplemented by open-ended discussions. DT underlines: *"You first need to know what the current behaviors are before you can assess where changes need to be made"*. Lifestyle information, including existing physical activity levels, dietary habits, and stress patterns, is registered and becomes available to the multidisciplinary HCP team through the electronic patient record, as it can significantly affect patient progress. Patients with healthy habits may adapt more easily to recommendations and reach goals faster, so the pace of change can be personalized. Additionally, DT emphasizes the importance of prior lifestyle in tailoring education, highlighting the need for insights into the necessity for new health behaviors, especially for patients with limited awareness of their habits. However, participants note that patients' recall of their exercise routines and eating habits is not always accurate, posing challenges in setting appropriate goals.

Work patterns and routines are also considered when designing treatment plans, as they could often interfere with the new types of behavior patients need to learn. PM exemplifies: *"People who are used to cycle to work instead of taking the car, especially for physical activity behavior, that's really important. [...] But if you always took the car, it is difficult to start to cycle to work"*. Participants observe a trend among patients with demanding jobs and hectic schedules who struggle to find time and energy for exercise or counseling sessions. In such instances, HCPs must provide flexible counseling options and alternative training methods while offering stress management support. Understanding household and family responsibilities is also vital, as they influence patient priorities and adherence to recommendations. HCPs tailor suggestions to match the patient's priorities to enhance their overall quality of life. SP recalls about a young patient with children: *"if they [i.e., a patient] have to prioritize the things they have to do, they choose for their children, then physical fitness and then work [...] so we adapt the training [...]. First month of rehab focus on family, and then pick up pace in exercise"*.

Resources In and Around Home. Regarding more practical factors, participants highlight the impact of income status on therapy adherence and long-term self-management. While insurance companies in the Netherlands strongly support CR, higher-income patients may have easier access to healthier food resources and specialized trainers outside the hospital. HCPs consider a patient's financial situation to recommend affordable, nutritionally suitable food options aligning with cardiac restrictions. PM presents opportunities for suggesting alternative exercise options by using information about the patient's local environ-

ments, such as nearby parks or recreational facilities, for those unable to afford gym memberships or personal trainers.

4.3 Contextual Information About the Social Environment

All participants stressed the importance of understanding the patient's *social environment*, both in and outside the home. This information enables HCPs to anticipate or address challenges related to therapy adherence, such as a patient with family members exhibiting unhealthy eating habits. It also informs clinical decision-making, such as involving individuals from the patient's social network in treatment or engaging patients in peer groups.

Social Framework and Support. Participants concur that understanding the patient's social background, including marital status, cohabitants, friends, and children, is crucial for counseling and training across all lifestyle behaviors. As knowledge acquisition and application occur at home, the family can significantly impact the patient's progress, both actively and passively. While this isn't standard practice in CR and varies among practitioners, our participants conduct dyadic interviews and sometimes therapy sessions to address this. SP mentions: *"[. . .] if I see a patient and the partner next to them, I can treat them both, and it helps. But if you are alone, it's much more difficult"*. The patient and their informal caregiver are asked about lifestyle behaviors, family obligations, and tasks. This allows DT, for example, to provide dietary advice and information tailored not only to the patient but also to the family and caregivers. PT and NP illustrate instances where one family member must make lifestyle changes while another is responsible for cooking and grocery shopping. Participants also investigate the dynamics between patients and caregivers, including perceived support, recognizing that a lack thereof can impede therapy adherence or discourage participation in CR. On the other hand, excessive support can lead to over-protectiveness or anxiety. CP1 exemplifies: *"if the partner is anxious - the partner is checking 'Are you feeling okay? I think you are not feeling okay. Have you checked your pulse?' Well, that's not helping. Because then the patient doesn't get the trust they need to do things by themselves again"*. In such cases, professionals engage partners in consultations, provide structured guidance on supporting a family member with cardiac issues, and may even refer them to psychosocial therapy.

Connections with Peers. HCPs also appreciate gaining insight into the nature of peer support patients are receiving. Some participants encourage community building and bonding in their practice - in some cases, peer advice comes with a certain empathy and understanding the clinician cannot offer. Nonetheless, this approach is not standardized. CP1 describes: *"It depends on what your personal style is as a psychologist, I really try to get them talking to each other (in group sessions) because it can really be helpful. [...] They all have been through the same. There's a lot of understanding, and empathy, and understanding lowers stress. [...] it really can help you [the patient] be calmer, be safe. [...] They can really confront each other in an easier and better way than I would do that"*.

Professionals may suggest online communities or group sessions to patients who lack peer contact.

4.4 Contextual Information About Mental Well-Being

Information about *mental well-being* can help identify the roots of existing challenges such as low patient progress or adherence. Patients are screened for depressive disorders and anxiety using standardized questionnaires (e.g., Beck Depression Inventory [66]). Throughout rehabilitation, patients share their mental challenges through open-ended discussions with HCPs, who communicate them to the multidisciplinary team, leading to collaborative care adjustments.

Depression and Anxiety. HCPs prioritize investigating if patients have a predisposition to anxiety, depression, or mood problems, which can hinder confidence and self-efficacy. Patients with a history of these issues or with a type-D personality [62] characterized by negative affectivity and social inhibition may require special psychological attention. SP explains that addressing depressive symptoms first is crucial, as they can impede treatment progress and patient empowerment. Patients who have experienced a cardiac event before participating in CR may face worries about their future and the trauma of the heart attack. This trauma can lead to anxiety about being physically active again, resulting in inactivity, lack of motivation, and, ultimately, depression. CP1 recalls: *"I recently had a patient and he had a stroke, and he was somewhere far away from home. He's really scared to walk alone in the dark because he's so scared that it will happen again. And he's really having panic attacks as well, really hyper-alert"*. Patients in need are referred to a clinical psychologist to address emotional challenges. Group sessions are recommended, while individual sessions and Eye Movement Desensitization and Reprocessing (EMDR) therapy [91] are offered to those dealing with trauma. It is important to note that this information may not always emerge at the onset of rehabilitation, as some patients may be hesitant to open up or discuss intimate thoughts and feelings. Rather, contextual information about psychological challenges is continuously collected, and most times, patients need to recognize these challenges themselves and ask for help. NP mentions that oftentimes, anxiety spikes after the program ends when the patient is left with little to no professional support at home.

Motivation and Health Beliefs. Participants document motivational levels during HCP-patient discussions, recognizing low motivation as a primary barrier to behavior change, program attendance, adherence, and completion. While pinpointing the exact causes for low determination is challenging, participants look at factors such as high anxiety, unhealthy coping mechanisms, low self-efficacy, and personality traits that contribute to low motivation. Professionals acknowledge that individuals with low self-efficacy for exercise need encouragement and reassurance of achievable progress. For instance, the sports physician (SP) empowers patients by forecasting their physical fitness post-program and demonstrating ongoing improvements, showing that exercise goals are achievable. They explain: *"If they [i.e., the patients] understand that they have a choice*

either to have a lower life expectancy but also lower physical fitness with its consequences or a possibility to gain this physical fitness, then most people will choose the physical fitness. [. . .] But that's what patients don't realize themselves. They have to be explained that that's possible". By also altering treatment and treating various anxiety or mood problems, motivation can be positively influenced. Furthermore, understanding patients' beliefs about their health situation is crucial contextual information. CP2 uses attribution theory [47] to grasp patients' perceptions and attitudes about their condition, while DT focuses on influencing negative beliefs about lifestyle changes by educating them on the consequences of unhealthy nutrition: *"Most of the time they don't think they eat that unhealthy or that it [i.e., unhealthy eating] has that much of an influence"*. Negative health beliefs can stem from difficulty accepting the diagnosis and viewing the body as "failing". CP1 illustrates the challenge of emphasizing the importance of rest to overly active patients who struggle to adjust their pace after a cardiac event.

4.5 Contextual Information About Physical Well-Being

Physical well-being is paramount in a patient's circumstances, as physical pains and limitations can impede lifestyle improvements, particularly in enhancing physical activity behavior. HCPs look into how comorbidities and the patient's subjective perception of symptoms hinder progress and offer personalized tools or suggestions.

Comorbidities and Limitations. Patients with CVD generally have other long-term chronic conditions, such as diabetes or chronic obstructive pulmonary disease (COPD), which can negatively affect the uptake of CR recommendations. Participants stress that comorbidities can impact the patient's perception of the severity of the cardiac condition and its implications for the future, thereby affecting patient physical and mental progress. Additionally, the presence of comorbidities like diabetes or cancer can diminish motivation and reduce the energy and time available for CR. HCPs heed energy levels, health perception, and life outlook related to comorbidities to comprehend why some patients lack motivation to improve their health. Clinicians can suggest alternative physical activity plans for patients with comorbidities like obesity, arthritis, or COPD by considering physical limitations such as knee pain, fatigue, or breathing difficulties. The sports physician (SP) and physiotherapist (PT) adjust exercise difficulty and the pace of lifestyle changes for these patients. SP highlights how individuals with chronic conditions adapt their behavior to physical limitations: *"There are people who have such bad lungs and still work full time. But they have learned to work very slow. [...] And the people that accept their condition, they walk maybe with a rollator [i.e., walker] or with an electric bicycle, they walk more slowly and they take more time, they finish the physical activity and they also take rest"*.

Perceptions of Symptoms. Perceiving symptoms accurately in relation to the cardiac condition is deemed crucial for patients to manage their health effectively. Participants emphasize clinicians' duty to gather data on perceived symptoms

and educate patients on symptom recognition to ease anxiety from misinterpretations. CP1 highlights that post-cardiac event, patients often become hyperaware and misinterpret symptoms, leading to stress, anxiety, and insecurity: *"After a stroke, you feel the vulnerability of your body. [...] you monitor your body, and that makes you feel a lot more aware of it. And that can lead to misinterpretation because, for example, you feel your heartbeat after you walk up the stairs. Maybe it was the same before. But now they think 'Maybe it's a stroke' [...] They get really anxious"*. Participants advocate for self-awareness, self-reflection, and respecting the body's boundaries by prioritizing rest when necessary. CP2 and PT underscore the importance of breaking a harmful cycle: misinterpreting bodily signals leads to anxiety, which in turn instills fear of movement. Clinicians aim to uncover the underlying causes of symptoms and complaints by inquiring about physical discomfort, fears, and concerns.

4.6 Contextual Information About Leveraging Knowledge

Providing knowledge is central to CR programs, and understanding and applying it is key to long-term behavior change. Patients receive extensive educational materials during the program, but this diminishes after discharge. They are educated about their diagnosis, rehabilitation procedures, and prognosis, with each piece of information being significant. HCPs make efforts to document and use information regarding patients' *ability to leverage knowledge* for therapy improvement in their practice.

The Ability to Absorb Knowledge. During consultations, participants try to adapt the difficulty of the educational materials to the level of understanding of the patient. Even though they try to simplify clinical language, it is sometimes difficult to grasp whether a patient has understood the information. For instance, SP describes that in some cases, patients who are not literate do not feel safe enough to communicate their need for assistance in comprehending the provided information. Detecting early signs of this reluctance can be detrimental to their health and progression. Patients receive information orally and in writing, being allowed to express any uncertainties. HCPs also inquire about self-acquired information sources to prevent patient misinformation. NP describes: *"I think it's important to see how the patient gets their personal information. Is it by talking with other patients who also had a heart attack? Or is it a professional or is it on the Internet to see reviews from medication, for example, that are also clinical?"*. Participants express their struggle with helping patients filter through the right information at home. Sometimes, patients base important decisions such as stopping medication intake on self-found knowledge. Participants mention that misinformation can also lead to a lack of interest in the program. HCPs stress the importance of gathering patient feedback to enhance the relevance and usability of provided information, with the goal of improving patient knowledge and understanding. PM recounts the impact of non-personalized educational sessions, noting low engagement levels and the need for content alignment with individual experiences. They highlight the challenge of maintaining interest when the

content doesn't directly relate to the patient's condition, suggesting a need for tailored information delivery.

The Ability to Implement Knowledge. NP partly attributes the lack of motivation to the patients' low ability to use what they learn in the program in real-life situations. During consultations, clinicians may inquire about challenges patients face during the practical application of clinical recommendations to achieve set goals (e.g., eat less fatty foods) and suggest personalized adjustments or interventions accordingly. They utilize patient narratives to pinpoint obstacles like difficulty in adjusting daily schedules to rehabilitation activities or the lack of self-efficacy and confidence to maintain a behavior.

5 Discussion

Our research was motivated by the misalignment between current CTR practices and holistic, co-located CR approaches. While CTR relies on telemonitoring data that quantify CR behaviors for HCP decision-making in lifestyle coaching, co-located CR aims to understand the patient comprehensively, a sum of behavioral, spiritual, physical, and situational factors [99]. To improve the alignment between CTR monitoring practices and co-located CR care, we first need to understand the types of contextual information that HCPs consider in their decision-making process within specific hospitals. This study identifies five kinds of contextual information about patients' daily lives used in Dutch CR (i.e., everyday normality, social environment, mental and physical well-being and ability to leverage knowledge). While CTR offers accessible CR programs, its current design provides HCPs with information disconnected from the individual and fails to capture the dynamic nature of a patient's daily life. Although achieving this fully may be challenging, we argue that objective behavioral data should be complemented by a more sophisticated understanding of the patient's context through open data collection methods that capture information related to the five identified categories. We discuss implications for the design of more holistic CTR telemonitoring below.

5.1 Aligning with Co-located CR: from Objective to Situated Data

As Martinez et al. [33] mention in recent work on cardiac technologies, *"design work is and should always be context-specific"*. Although telemonitoring technologies have become pervasive in CR [36,55], they (1) present HCPs with data that quantify and characterize behaviors in isolation from the patient's situated context (e.g., [25,52]), and (2) lack the means to capture contextual information and present it in a meaningful and useful way to clinicians. Our study shows that the current telemonitoring paradigm in CTR does not align with current co-located CR practices.

Previous work on health technologies for rehabilitation emphasizes looking beyond automated data collection and quantification of behavior. Bhat et al. criticize the negative spaces in health datafication, underlying the omission of

information from alternative subjective sources [19]. Tadas et al. [94] advocate for designing cardiac technologies that reflect patients' everyday lives and individual differences. In their later work on CTR, they stress the importance of combining *automated data with subjective patient experiences* [95], signaling a shift in clinical decision-making toward considering the *situated objectivity of data* [78]. With a similar motivation, Akinsiku et al. propose a paradigm reconceptualization for situated stroke telerehabilitation systems that capture the lived experiences of patients next to their movement data [2]. Driven by a missing comparable investigation in the context of CTR, we examine the information outlining the situatedness of patients' behavior in CR used by HCPs to make clinical decisions, and we urge designers of cardiac telemonitoring technologies to include *subjective and non-automated data collection methods* as a circumstantial completion of behavior data that can help clinicians provide tailored, holistic care (Fig. 1).

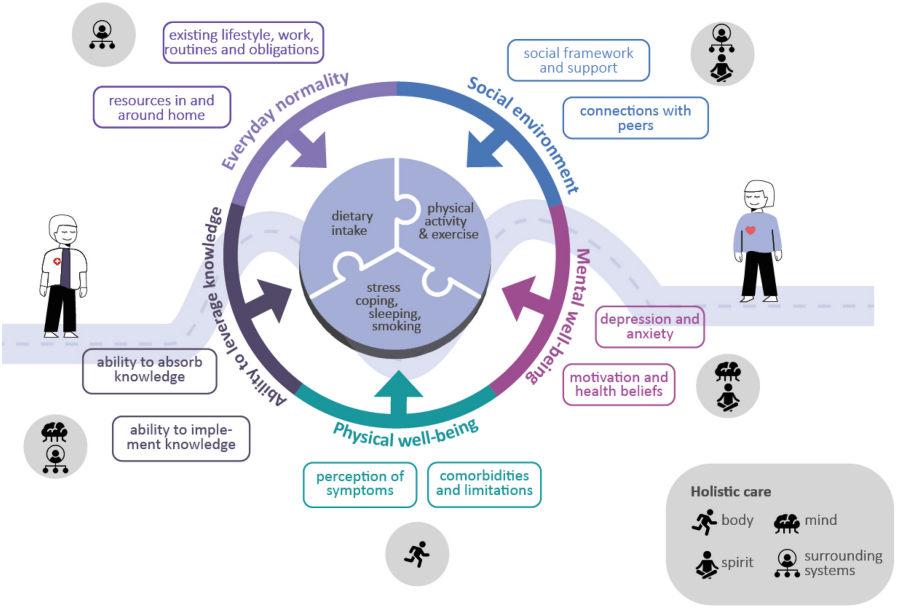

Fig. 1. Types of contextual information that could be captured by holistic CR telemonitoring aligned with holistic care principles [99].

Our investigation into co-located CR revealed that contextual information is gathered during periodical doctor-patient interviews, documented through open note-taking by clinicians, and serves as a shared knowledge base for the multidisciplinary team [13]. HCPs utilize contextual information to address barriers in patient adherence to CR components, with data collection methods relying on common sense, experience, and subjective perspectives. In CTR, a dynamic

action-reaction process occurs, where clinicians observe red flags or negative trends in automatically collected data and respond accordingly [52]. In transitioning to a more nuanced approach to data-based decision-making, we advocate for a more *open approach to data collection*, which is backed by recent research findings [2,95]. Open approaches refer to less structured, *more spontaneous collection moments and alternative, expressive, and qualitative data-gathering methods* beyond standardized questionnaires and passive sensors. Examples can include functionalities that allow patients or clinicians to annotate behavior data through open text fields at any time, prompting impromptu questions to patients and incorporating more diverse data types such as audio or video recordings, pictures, or short diaries. One example is the recent design of Chromatize, a flexible, manual self-tracking application by Barker-Canler et al. [15]. These approaches can help avoid the de-personalization of CTR data and care [11]. While exploring open approaches to telemonitoring, designers must consider *HCPs' workflows and patient self-reporting burden* [57,81]. Involving clinicians and patients in designing data collection methods can mitigate workload and reporting overload [20]. This can be done, for example, by following Andersen et al.'s [6] conceptual guidelines for addressing divergent patient-clinician concerns and designing data collection and representation features in line with key characteristics of physician's progress notes (e.g., [13]). For instance, Seals et al. [89] recommend visually connecting objective data with clinical goals and patient narratives for efficient access to important information. Contextual information within CTR can serve as a semantic layer to behavior data, providing "details on demand". Moreover, our insights, supported by previous work [4,48,89], highlight the importance of *patient-clinician relationships, discussions, and shared reflections*, indicating that data visualizations should support patient-clinician conversations, accommodate low levels of data literacy, effectively convey progress or trends, and illustrate clinician explanations effectively. Lastly, it is worth noting that objective data can sometimes evolve into contextual information [2]. For example, details about a patient's diet can help a sports physician explain a decrease in energy affecting overall functional capacity. To achieve this, telemonitoring interventions should be able to collect a comprehensive dataset covering all key CR components. As emphasized in the recent study of Goevaerts et al. [46], such solutions are infrequent and need further development and exploration.

5.2 Implications for Collecting Contextual Information

Our research argues that telemonitoring systems should capture diverse patient contextual information through open data-collection methods to help clinicians personalize therapies, and align patient goals with health goals and recommended lifestyle changes [33,96]. Our findings align with Akinsiku et al. [2] on the experiential information needed in stroke rehabilitation, such as mental and physical health, motivations, and fears. We add to this by addressing the complexities of the CR context, including nuanced needs regarding knowledge absorption, patient lifestyles, and social dynamics. We offer recommendations on how to capture such information in CTR.

The Everyday Normality. We find that understanding the patient's health habits, work patterns, routines, and home resources is crucial for HCP's collaborative goal-setting, problem-solving, calibrating clinical objectives, and adjusting therapies, as it contextualizes behaviors in the patient's lived environment. CTR telemonitoring technologies should:

- prompt questions about a patient's everyday normality at program onset, creating a shared database for the multidisciplinary team to make collaborative and individual treatment decisions – e.g., knowing a patient's routines aids in tailoring training intensity, pace of change, and recommended schedules, such as whether they walk or drive to work or if they have a dog to walk each morning.
- prompt patients to periodically, throughout the program document significant changes in their everyday normality, allowing for customized therapy adaptations (as illustrated in Tadas et al.'s intervention [95]) – e.g., economic issues, family obligations, or work priorities can impact patient adherence to CR adherence, and lacking this contextual information can lead to high drop-out rates and hinder behavior maintenance [51].

The Social Environment. Information on social support, family dynamics, and peer interaction is vital for HCPs. Although previous research underscores the pervasive role of family and informal caregivers in long-term lifestyle change [83], remote cardiac care falls short in addressing the transitional dynamics of a patient's social relationships [72]. CTR telemonitoring technologies should:

- collect comprehensive information on stakeholders involved in long-term lifestyle changes at home, including family status and levels of social support in various activities (e.g., exercising with friends, cooking with a spouse) at program onset. This aids in deciding on family involvement or individual interventions for caregivers, as partner distress or noncooperation can adversely affect patient well-being and adherence in CR [24].
- formalize family or informal caregivers' roles in telemonitoring (e.g., by enabling them to participate in data collection). This can provide insights into the patient's and family's lifestyle changes and coping mechanisms. Family-centered remote care interfaces and caregiver input options are essential [2,8,39,90,104] but still underexplored in interface design.
- enable patients to express social challenges and needs they might hesitate to voice during in-person consultations, facilitating support for family obstacles and connecting with other cardiac patients for community support.

The Mental Well-Being. HCPs extensively utilize information about the patient's depression, anxiety, motivation, and health beliefs to build profiles, prioritize clinical goals, recommend suitable therapies, and intervene during low morale. CTR telemonitoring technologies should:

- enable mental health assessment using validated questionnaires (e.g., the Beck Depression Inventory [66]) before, during, and after the program. CTR sys-

tems often lack mental health tracking [51,65] – one existing example is the LifeStyleScore app that periodically assesses perceived stress [46].
- enable and empower periodic self-reflection by allowing patients to augment objective data overviews with other mental factors (e.g., motivation, health beliefs, psychological struggles) and insights from their decision-making processes. Such data is essential to clinicians but is overlooked, although its absence has been proven to hinder proactive CTR dropout prevention [52].

The Physical Well-Being. Participants also rely on information about the patient's other chronic conditions, physical pains, symptoms, and side effects during consultations, physiotherapy sessions, or patient calls to provide tailored therapy recommendations. CTR telemonitoring technologies should:

- record the range of comorbidities at program onset and enable periodical logging of physical complaints (e.g., [53,75]). Pain, its timing, medication side effects affecting physical well-being, and complaints due to comorbidities can significantly contribute to program dropout if not addressed in time [52].
- prompt the patient's subjective perception of symptoms alongside commonly monitored vital signs such as blood pressure and heart rate [8,12] throughout the program. Overanalyzing body signals can lead to fear of movement and exercise. Sampling patients' subjective perception of felt symptoms has been encouraged before [5,7], as its clinical validation can create in-the-moment knowledge about recognizing one's body signals for patients [96].

The Ability to Leverage Knowledge. The patient's understanding of educational materials, information during consultations, and ability to implement recommendations in daily life are essential for successful CR adherence and long-term lifestyle change [93]. CTR telemonitoring technologies should:

- provide means for patients to express concerns and needs regarding overwhelming or confusing information. Patients should be able to provide open feedback electronically or comment on clinical recommendations and educational materials as an outlet for expressing a lack of understanding (e.g., Tadas et al.'s weekly open questionnaire [95]) or inform clinicians about concerns arising from unreliable information sources (e.g., as supported in Ongwere et al.'s work [76]). This can help clinicians prevent misinformation and provide educational materials adapted to patients' understanding levels. Such adaptations have been explored in interventions like Gibson et al.'s tablet application for adults with mild intellectual disabilities [45].
- gather evidence not only on behavior change trends but also on the patient's self-efficacy and reasons behind challenges they face in practical knowledge implementation outside the hospital environment.

6 Conclusion

This study presents multiple perspectives on using patient contextual information in clinical decision-making in Dutch CR, defining its types and impact on

lifestyle coaching and counseling. We discuss implications for holistic telemonitoring inspired by our results, including ways to gather and use identified contextual data in CTR. We advocate for a shift in designing telemonitoring systems that incorporate open, more flexible data collection approaches that support the "situated objectivity" of behavior data, making it meaningful for HCPs by closely aligning it with patients' individual identities. Enhanced telemonitoring can make data more actionable, but designers must consider trade-offs like clinician workload and patient self-reporting burden. While comprehensive data collection is challenging, emerging open data collection approaches (e.g., [15,19]) offer potential. Future work should also raise multi-stakeholder awareness about the importance of considering patient context in CTR intervention design.[2]

A Appendix

A.1 Patient Barriers and Facilitators in CR Presented on the Miro Board

Table 1. Barriers and facilitators of patient behavior in cardiac rehabilitation utilized to create the Miro board visualization used in the interview.

Category	Contextual factors
Socio-demographic	age, profession, educational level, income status, race, gender, family composition, relationship status, social support, family/home obligations, available free time, routines and habits, upbringing, previous lifestyle, geography around the home, living situation, insured/not insured, culture and religion
Practical and resource-related	transport to the center, distance to the center, endorsement by the HCP, length of the program, quality of the program, similar exercise opportunities around the home, safe environment in the program, amount of suggested changes, timing between hospitalization and the beginning of the program, timing of the information, support after the end of the program, inclusion of the partner in the program, personalization of the program, quality and quantity of the information, information provided to the partner, chosen goals
Psychological, cognitive, and personality-related	depression, anxiety, mood problems, anxiety to perform physical activity, self-efficacy, confidence, motivation, familiarity with one's body, trust in the efficiency of the program, ability to negotiate with oneself, self-control, ability to understand information, ability to self-reflect, ability to manage one's time, self-awareness, personality type, perception of symptoms, beliefs about the illness and treatment, perception of consequences of illness, coping mechanisms, resourcefulness, self-esteem
Clinical and physical	other comorbidities, physical fitness, physical activity levels, self-sufficiency, presence of symptoms

The list above identifies barriers and facilitators affecting patient behavior during and after CR. In the absence of studies documenting information used by clinicians in CR to guide lifestyle coaching and counseling, we select studies whose aim is to understand why patients face difficulties in completing CR programs in order to improve the programs. The review aimed to develop a supporting overview that could guide the conversation with the participants. The

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list has been compiled by looking at (i) various behavioral models (e.g., biopsychosocial [23,44], socio-ecological [38,74], Com-B [102], trans-theoretical [82], and Fogg Behavior Model [42]) as well as (ii) a representative corpus of studies which explore diverse sources of barriers and facilitators in CR ranging from patient interviews to medical records (e.g., [29,68,103]), investigations into patient dropouts at different stages like CR uptake, adherence, completion or self-management (e.g., [14,21,64,87]), or barriers of specific sub-groups such as women or rural patients (e.g., [1,9,41,60]) (Tables 1 and 2).

A.2 Participants

Table 2. Participants; information about their role and expertise was gathered from the interviews, as well as public websites with the participants' consent

Participant ID and expertise	Experience and role
CP1 - Clinical psychologist at the Department of Clinical Psychology in a teaching hospital	They consult patients in cardiac rehabilitation, geriatrics, and oncology. Specialized in trauma treatment with EMDR (Eye Movement Desensitisation and Reprocessing) [91], they assess psychiatric and psychological problems (that were already present or developed after the cardiac event), supervise psycho-educational prevention modules (group sessions), and offer individual treatment of patients if necessary.
CP2 - Clinical psychologist, psychotherapist, and tobacco addiction specialist working in a CR clinic	With decades of experience, they hold a similar role to CP1. They also help patients during the smoking cessation process.
SP - Sports physician specializing in injury treatment, chronic conditions, and vascular problems, working in a teaching hospital	With decades of experience, they help patients with chronic conditions improve their physical fitness. They are nationally involved in developing exercise tests and training programs for patients with heart disease, lung disease, and cancer. They conduct cardiopulmonary exercise testing, formulate training recommendations, offer consultations for discussing test results and recommendations, supervise results of exercise stress tests [86].
NP - Nurse practitioner specialized in cardiac rehabilitation	With decades of experience, they hold the title of "case manager", i.e. patient advocate that supports, guides, and coordinates patient care. They conduct intake sessions for discussion of lifestyle behavior/changes and individual goals, perform assessments for risk for anxiety and depression, and end evaluation of the CR program.
DT - Dietitian and researcher in nutrition	With a Ph.D. in dietary assessment, they have practiced as a dietitian. They perform work on advancements in dietary assessment and the use of data for health behavior research. During the CR program, dietitians assist patients in making better dietary choices.
PT - Professor of physiotherapy and former physiotherapist in a cardiac rehabilitation center	With a Ph.D. in factors influencing rehabilitation outcomes they teach physiotherapy at the University. They have years of experience as a physiotherapist in a CR clinic. As a physiotherapist, they supervise the individually tailored exercise training program and are a supporter of a physically active lifestyle.
PM - Professor of behavioral change and former project manager in a cardiac rehabilitation hospital unit	With a Ph.D. specializing in cardiac telerehabilitation programs, they develop lifestyle interventions to prevent chronic conditions. Previously a hospital project manager in the CR unit, they were responsible for conducting research and developing efficient CR programs for patients together with clinicians.

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