Assessing the Value of Digital Tools for Effective Shared Decision Making on Physical Activity in Cardiac Secondary Prevention

Peer-reviewed author version

CONINX, Karin; BABAEI BALDERLO, Shahrzad; RAMAKERS, Wim; KIZILKILIC, Sevda; SEGUNDO DIAZ, Rosa Lilia; DENDALE, Paul & HANSEN, Dominique (2026) Assessing the Value of Digital Tools for Effective Shared Decision Making on Physical Activity in Cardiac Secondary Prevention. In: Hu, J., Coninx, K., Yu, B., Borzì, L., Houben, M. , J. (Ed.). Pervasive Computing Technologies for Healthcare, Springer, p. 387 -406.

DOI: 10.1007/978-3-032-27582-0_24
Handle: http://hdl.handle.net/1942/49739

Assessing the value of digital tools for effective shared decision making on physical activity in cardiac secondary prevention

Karin Coninx[1] [0000-0001-6730-3426], Shahrzad Babaei Balderlo[1] [0009-0003-7999-4414], Wim Ramakers[1][0000-0003-0768-1067], Sevda Ece Kizilkilic[2,3,4] [0000-0003-3658-7854], Rosa Lilia Segundo Díaz[1] [0000-0002-9973-8712], Paul Dendale[2,3] [0000-0003-0821-4559], and Dominique Hansen[3,5,6] [0000-0003-3074-2737]

[1] Human-Computer Interaction and eHealth, Faculty of Sciences, Hasselt University, Agoralaan Building D, Diepenbeek, 3590, Belgium
karin.coninx@uhasselt.be
[2] Faculty of Medicine and Life Sciences, Hasselt University, Agoralaan Building D, Diepenbeek, 3590, Belgium
[3] Heart Centre Hasselt, Jessa Hospital, Stadsomvaart 11, Hasselt, 3500, Belgium
[4] Faculty of Medicine and Health Sciences, Ghent University, Corneel Heymanslaan 10, Ghent, 9000, Belgium
[5] BIOMED (Biomedical Research Institute), Hasselt University, Agoralaan Building C, Diepenbeek, 3590, Belgium
[6] REVAL (Rehabilitation Research Centre), Hasselt University, Wetenschapspark 7, Diepenbeek, 3590, Belgium

Abstract. Physical activity is a key component in secondary prevention for patients with cardiac disease. Patients often face challenges to reach and sustain an appropriate level of physical activity. While guidance of caregivers is essential in the initial stage of rehabilitation, personalised approaches that take into account patient preferences provide opportunities for successful lifestyle interventions. In a recent RCT, we evaluated such a shared decision making approach that includes patient preferences for physical activity. Both caregivers and patients were supported by digital tools. Results of the RCT show the effectiveness of shared decision making supported by digital tools on physical activity. Quality of life and exercise capacity significantly increased after the 12-week intervention, and a significant increase in daily step count was observed in the intervention group. In this paper, we present a secondary analysis of the collected data from a Human-Computer Interaction perspective, in search of the added value of digital tools in effective shared decision making. With this aim, we depict our hypotheses as a theoretical model with technology-related and rehabilitation process related constructs and investigate their correlation with the outcomes. This approach enhances insights in factors that determine the effectiveness of digitally supported shared decision making. Although the model cannot extensively clarify all contributing factors, the secondary analysis reveals a need for personalisation.

Keywords: shared decision making, physical activity, adherence, cardiac disease, mHealth.

1 Introduction

After suffering from a cardiac event or when being diagnosed with a cardiovascular disease, patients should be referred to cardiac rehabilitation or a secondary prevention trajectory [1], [2]. Cardiac telerehabilitation is an interesting alternative for patients that experience barriers to attend centre-based rehabilitation, such as transportation problems or scheduling problems in combination with their job, and has proven to be effective [3] and cost-effective [4]. Research efforts also explore the combination of centre-based and telerehabilitation [5], to come up with flexible but intensive rehabilitation trajectories [6]. It is indeed observed that tailoring is limited in most rehabilitation trajectories. Former research found that true involvement of patients in decision making improves satisfaction, adherence, and health outcomes [5], [7].

To evaluate the effectiveness of shared decision making (SDM), supported by digital tools, in cardiac rehabilitation for secondary prevention, we performed a randomised controlled trial (RCT)[8]. The SharedHeart study was approved by the ethical committees of Jessa Hospital and UHasselt. While contemporary cardiac rehabilitation preferably engages patients in a comprehensive trajectory, integrating different components such as physical activity training, healthy nutrition advice, medication management, education and support for smoking cessation and stress management, our study focused on a SDM approach for physical activity. The control group participated only in centre-based rehabilitation sessions and was motivated to train at home without concrete support, whereas the intervention group engaged in a hybrid trajectory. In addition to the centre-based rehabilitation sessions, participants in the intervention group were guided in shared decision making encounters facilitated with the SharedHeart dashboard, and their home-based training was supported by the SharedHeart mobile app.

The results of the RCT show significant between-group differences for the primary outcome, change in quality of life (HeartQoL questionnaire [9]) and for the secondary outcomes, among which the increase in exercise capacity (VO_2 peak) and increase in physical activity level (change in average daily steps). These findings confirm the enhanced effectiveness of the applied hybrid shared decision making approach compared to the centre-based rehabilitation only. However, given several differing factors between the intervention group and the control group, including the use of the SharedHeart mobile app and the shared decision making encounters supported by the SharedHeart dashboard, it is not straightforward to determine the dominant factors of the approach that cause the superiority of the digitally supported SDM trajectory.

In this paper, we report on a secondary analysis we performed in search for determining important components of the applied digitally supported SDM. A mixed-methods approach is followed, and we ground the analysis on findings from literature. More specifically, we constructed the theoretical model visualised in **Fig. 1** to frame our analysis and rationale.

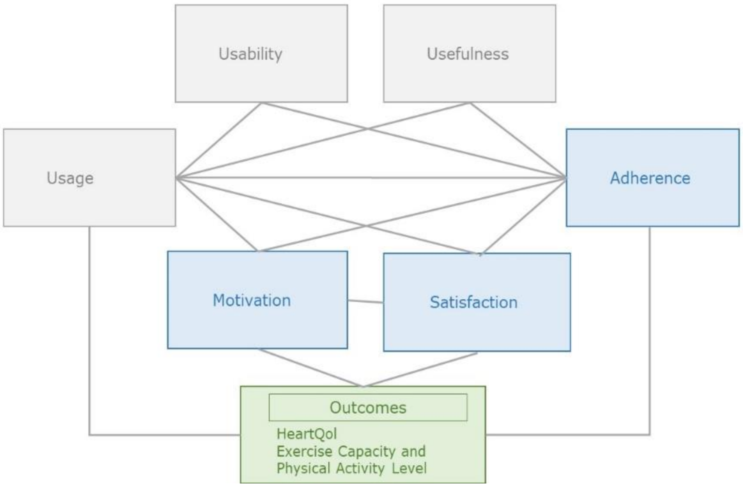

Fig. 1. Theoretical model with hypothesised correlations between constructs represented by coloured rectangles. Constructs in grey rectangles are technology related, blue rectangles relate to the rehabilitation process, and outcomes are represented in green.

The rationale is that SDM is known to improve the satisfaction on the rehabilitation approach [7], [10], so we are wondering if the satisfaction correlates to the outcomes and what the satisfaction is influenced by. As guideline-based exercise prescriptions are used [11], [12], it can be assumed that higher adherence to the therapy positively influences the outcomes [13]. From our Human-Computer Interaction perspective, we are particularly interested in the role digital technology can play to reach positive results in an SDM approach. The upper left part of the theoretical model is inspired by the TAM Technology Acceptance Model [14], [15], [16], [17], which includes the assumption that people's intention to use technology is (indirectly) influenced by its usability / ease of use and its perceived usefulness. Furthermore, we hypothesise that usability and usefulness eventually lead to better adherence, as measured by reporting via the mobile app. This perspective on adherence seems conceptually linked to sustained usage of the mobile app. Intuitively, one expects motivation to influence the rehabilitation trajectory and its outcome. In a digitally supported SDM approach, it is hypothesised that the application contributes to motivating the rehabilitating person to sustain the physical exercise efforts. Being aware of good adherence, is also hypothesised to positively influence the motivation to exercise.

In the remainder of this paper we describe the methods applied for the secondary analysis. After highlighting some results for individual constructs from the theoretical model, we report on correlations that were found between the constructs. We conclude by reflecting on the gained insights and limitations of this study, as well as implications for future designs of applications supporting shared making.

2 Methods

2.1 Summary of the RCT study

The SharedHeart study was a monocentric, prospective randomised controlled clinical trial for which patient recruitment took place in Jessa Hospital (end 2022 – end 2023). 80 cardiac patients were recruited and randomised 1:1 to the control group or intervention group. Study duration per participant is 12 weeks, and primary outcome was quality of life [9].

Both the participants in the control group and in the intervention group followed regular centre-based rehabilitation, consisting of 2 or 3 supervised training sessions a week.

The patients in the intervention group received additionally an SDM approach supported by digital tools: a tablet application used in their initial visit to select physical activity preferences, and a mobile app to manage their physical activity also at home. Features of the mobile app are intended to increase adherence to the training program and include: plan and report their physical activities (structured exercise and other daily activities), check their progress with respect to the weekly training goal, consult educational videos, and work with personalised exercise programs.

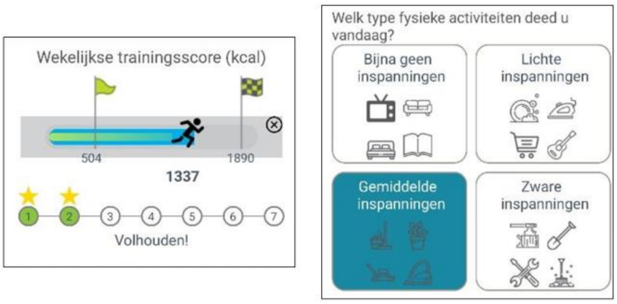

Fig. 2. Snapshot – cropped screenshot from actual SharedHeart mobile application - showing weekly training goal (left) and daily activity reporting (right) in mobile app.

The dashboard allows caregivers to monitor the physical activity reports of their patients. Furthermore, the dashboard for caregivers was designed in such a way that some parts facilitate communication between patients and caregivers (cardiologist or physiotherapist) during an SDM encounter. For instance, the training program and progress over the weeks is visualised to be understandable for patients and to facilitate discussion. SDM encounters are not shaped as extra visits on top of the centre-based training sessions, but some sessions are transformed in an SDM encounter by using the dashboard to give feedback on the patient's performance and involve the patient in decisions regarding the training program. During the first 6 weeks there are weekly SDM encounters, after which they are planned every two weeks.

The dashboard also gives access to the EXPERT tool [11], [12], a decision support tool that recommends tailored exercise taking into account the individual health characteristics of the patient. The EXPERT tool is used in both groups of the study, but the mobile app guides the patients in the intervention group somehow to adhere to the exercise prescription.

We refer the reader to [18] for a more detailed description of the user-centred design process of the SharedHeart applications and the application features. The study design and results of the RCT from a medical perspective are published in the SharedHeart article in the European Journal of Preventive Cardiology[8].

2.2 Data collection

Rather than giving a detailed overview of all data that were collected in the RCT, we will limit ourselves to the most important data items that are considered in the secondary analysis (see **Table 1**).

Table 1. Overview of most important measures taken at T0 (start of rehabilitation or end of week 1), T1 (in the middle, around week 6) and T2 (end of study, mostly week 12), in control group (C) and/or intervention group (I). Representative selection of medical tests and questionnaires.

Measures	**T0**	**T1**	**T2**	**Groups**	**Notes / examples**
CPET	X	X	X	C+I	VO_2peak and related measures
HeartQoL	X		X	C+I	Quality of life (standard questionnaire [9])
Average daily step count	X		X	C+I	With Fitbit Charge
Diary of physical activity	X		X	C	Paper-based reporting of structured exercise and daily activities
Background questionnaire	X			C+I	Ad hoc questionnaire on demographics, digital and health literacy
Preferences questionnaire	X			I	Ad hoc questionnaire on physical activity preferences, via tablet application
Perception of rehabilitation questionnaire	X	X	X	C+I	Ad hoc questionnaire on motivation, satisfaction, anxiety, health literacy, involvement in rehabilitation and decision making etc.
General approach questionnaire			X	C+I	Ad hoc questionnaire on overall perception of rehabilitation
Design mobile app			X	I	Ad hoc questionnaire on design details and usability / usefulness
Application logs	X	X	X	I	App usage, used features
Semi-structured interview			X	I	Discusses user experience and perception of rehabilitation / SDM

2.3 Data analysis

In the theoretical model, introduced in the introduction, we mention the different constructs in a general way. More detailed measurements of the constructs, based on the collected data, are used to calculate correlations between the constructs to validate the theoretical model. An overview of the collected data used for the correlation calculations is presented in **Table 2**.

Table 2. Constructs as used in the theoretical model, and their measurement or collected data

Construct in the theoretical model	**Data collected / measurement used in correlation calculations**
Usage (structured exercise)	Total number of structured exercise reports completed by a patient over 12 weeks
Usability	The average per patient of their score for ease of use and ease of understanding for the whole application (each of which is rated via the ad hoc design questionnaire), taken at T2
Usefulness	The patient's score for the perception of usefulness of the whole application (rated via the ad hoc design questionnaire), taken at T2
Motivation for behaviour change	The patient's score for the question "How motivated are you at this moment to change your health behaviour through rehabilitation" (in the questionnaire Perception on rehabilitation), taken at T2
Motivation to engage in physical exercise	The patient's score for the question "How motivated are you at this moment to engage in physical exercise?" (in the questionnaire Perception on rehabilitation), taken at T2
Satisfaction with training program	The patient's score for the question "How satisfied are you with your current training program?" (in the questionnaire Perception on rehabilitation), taken at T2
Adherence (minutes)	For each patient, the average percentage over 12 weeks for the adherence to the EXPERT prescription, for the minimum minutes prescribed per week
Adherence (sessions)	For each patient, the average percentage over 12 weeks for the adherence to the EXPERT prescription, for the recommended number of sessions prescribed per week
HeartQoL	The global quality of life score calculated via the questionnaire HeartQoL, taken at T2
HeartQoL (Physical)	The sub-score for physical quality of life calculated via the questionnaire HeartQoL, taken at T2
HeartQoL (Emotional)	The sub-score for emotional quality of life calculated via the questionnaire HeartQoL, taken at T2
Exercise capacity	The value of Vo2max, measured at T2
Physical activity level	The average daily step count taken at T2

This secondary analysis is done with the data collected in the RCT. 80 patients were randomised, with 6 dropouts of 40 in the intervention group and 4 dropouts of 40 in the control group.

For the analyses in the current study, we maximally use participant data, but only when the data is available for all needed time points (T0, T1, T2) that are needed for that specific analysis. There is no strategy to complete missing data. This clarifies why the number of involved patients varies between 23 and 40, as indicated per analysis.

Data analysis for questionnaires with ratings was done with straightforward descriptive statistics. In addition, a number of correlations are calculated.

3 Results

3.1 User experience and Usage of the SharedHeart applications

In light of detangling the role of the digital tools in the effectiveness of the rehabilitation process with shared decision making, we considered the appreciation for certain features, the perceived usability, the perceived usefulness and usage of the mobile app.

In general, usability scores (five-item scales) for attractiveness of design (mean = 3.76, SD = 0.83), for ease of use (mean = 3.84, SD = 0.85) and ease of understanding (mean = 3.84, SD = 0.85) are high to very high. In **Fig. 3**, the rating for ease of use is shown as an example.

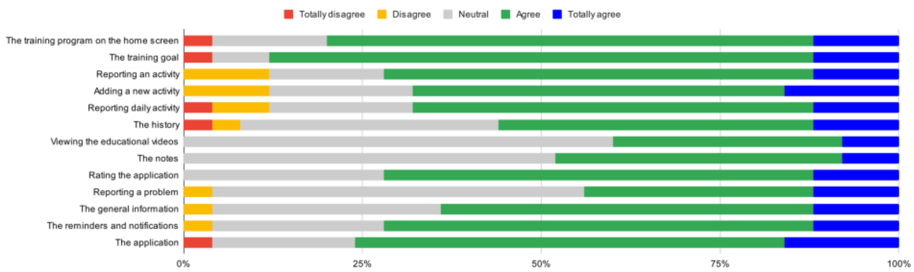

Fig. 3. Ease of use of the features of the mobile app, scored on a five-item scale (totally disagree – totally agree). Bars represent the fraction of participants (n = 25) per item of the scale.

Because a "Technology Acceptance" perspective has inspired part of our theoretical model, we also consider the rating for usefulness as shown in **Fig. 4**.

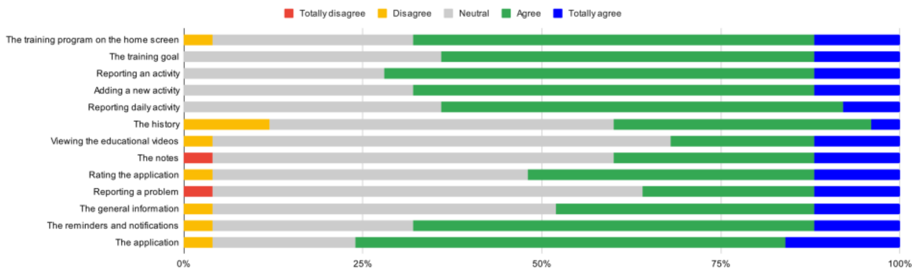

Fig. 4. Usefulness of the features of the mobile app, scored on a five-item scale (totally disagree – totally agree). Bars represent the fraction of participants (n = 25) per item of the scale.

The scoring for topics of usability and for usefulness was done for separate features of the app (e.g., the training goal, reporting an activity), and via a general impression on the integral application (lowest bar in figures).

It is well-known in human-computer interaction that true usage of an application is hard to measure via logging, e.g., because an app component is opened but the user switches temporarily to another task before continuing, and because the user works more efficiently with the application after a while. Therefore, we decided not to base our usage calculations on activation of certain components by the user, but rather on reporting physical activity. At the end that is an important aim of digital support, in preparation for other features such as visualisation of progress towards the weekly goal. In this way we calculated the average number of days per week that users report structured exercise training, some daily physical activity, either one or both. Separate usage information is displayed in **Fig. 5**.

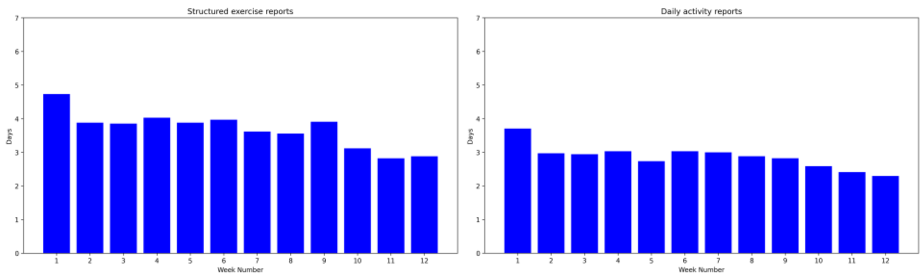

Fig. 5. Average number of days per week on which a user reports physical activity via the mobile app. Participants in analysis: n = 23. Left: structured exercise reports. Right: daily activity reports.

From this analysis, we conclude that daily activity reporting is done less than structured exercise reporting, even if there are usually more daily activities than structured exercise sessions. The interviews and quantitative user experience data indeed confirm that daily activity reporting is less appreciated, as illustrated by the following quote: "*I used daily activity reporting in the beginning but stopped after a while…I did not see what happened with it in the app and the physiotherapist did not ask for it either*". However, participants having difficulties to adhere to the structured exercise prescription value daily activities reporting more. Some of them reported frustration that those reports are not counted in to calculate progress towards the weekly goal, and they request more detailed and more varied daily activity reporting than currently supported in the SharedHeart mobile app.

3.2 Adherence and physical activity reporting

We emphasise that the training programs in the SharedHeart approach are guideline-based, which is realised by means of structured exercise prescriptions with the EXPERT tool [11], [12]. The FITT (frequency, intensity, time, type of exercise) formatted exercise recommendation is personalised for the patient's indication for rehabilitation and their risk factors. The EXPERT generated prescription is available in the app in a patient readable format via flag-represented minimal and optimal weekly exercise goals, and the number of sessions to be completed. The app helps to calculate the energy consumption of a reported or planned activity and predicts how it contributes to the weekly goals. Patient preferences are taken into account when suggesting physical activity types for the weekly training schedule that is decided on together with the caregiver during an SDM encounter.

The abovementioned flag representation of goals with a progress bar indicating their achievement is the main visualisation for patients in the mobile app. As patients report their performed activities in the mobile app, it is possible to compare this with their planned training schedule and the EXPERT prescribed level of structured exercise training.

For research purposes, we designed the visualisation in **Fig. 6**, which increased our insight in the diversity in participating patients for their adherence to the training program. It should be noted that the number of sessions per week varies over patients, in accordance with their EXPERT prescription. Typical examples are 3 or 5 sessions a week, or daily structured exercise.

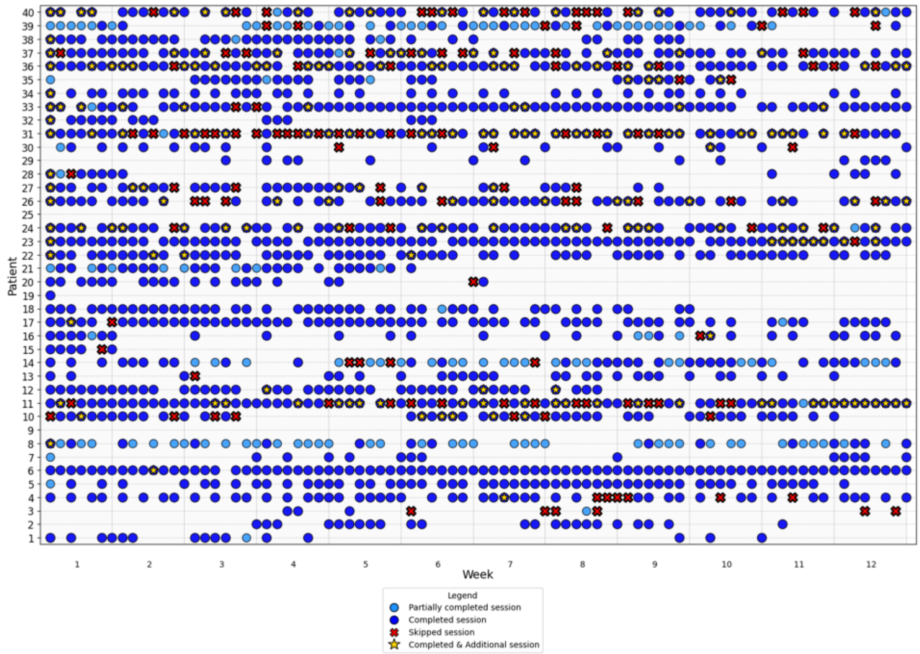

Fig. 6. Adherence to the training program over time, per patient (n = 40). Each symbol represents a structured exercise session with appropriate duration according to the EXPERT recommendation.

For adherence calculations in the context of the secondary analysis we worked with average percentage of completed structured exercise minutes per week and completed number of sessions, based on patients' reporting via the app. Inevitably, this self-reporting introduces a bias. Because adherence to therapy is based on self-reporting in the mobile app, this measure is to some extent aligned with app usage, but this also covers daily activity reporting.

Visual inspection of **Fig. 6** shows that there is a lot of variation for different participants in the intervention group, as well as variation over time. Some participants show a relatively consistent pattern over time of being highly or lowly adherent, whereas other patients' adherence fluctuates a lot. The figure also shows that some participants perform the planned exercise, but need the flexibility to move the session to another moment in the week. These findings point to a need for personalisation.

3.3 Motivation

In the SharedHeart study, we collected information on different kinds of motivation. With respect to the digital technology, we questioned the participants which features of the mobile app influenced their motivation to perform physical exercise. On the more general level, we were interested in the evolution over time of their motivation to perform exercise training. Furthermore, participants were specifically asked for their motivation to realise behaviour change, which in this context comes down to adopting a healthy lifestyle incorporating the advised amount of physical activity.

The quantitative results from the ad hoc design questionnaire reveal that participants have personal preferences for the application features they rate as the most motivational. Nevertheless, a number of features are considered motivational by most participants. Between 60% and 70% of participants "agreed" or "strongly agreed" with the motivational effect of: the program with scheduled training activities, the visualisation in the training program of achievement of the daily goal, the representation of the progress of the weekly training goal (flags representation), and the prediction that shows whether a planned physical effort will lead to achievement of the weekly goal. On the other hand, only between 30% and 50% of participants found the tips when not performing enough daily activity motivational, and the same applies for the message when reaching the weekly training goal, and the overview of activities in the history representation (calendar view).

Similar findings followed from the qualitative interview data. About the history, several patients expressed their thoughts as "*I'm not interested to check my performance on a specific day in the past via the calendar widget…I want to see my progress over weeks, that's more motivating*". In future designs the history feature in the app could be more similar to the flag representations over several weeks, as currently used in the dashboard, and that representation was welcomed by both patients and caregivers.

In contrast with our expectations, the quantitative data do not show a significant between-group difference for the motivation to engage in physical exercise (Mann-Whitney U test, U = 393.5, p = 0.63). This is visually represented in **Fig. 7**, which furthermore suggests that motivation generally not increases towards the end of the rehabilitation trajectory (T2).

However, case-based analysis of individual patients' evolution in motivation to exercise shows a diversity of patterns. For a number of patients, the motivation is relatively stable or slightly increases over time (possible because they enjoy increased capacity to exercise). Other patients show a dip in motivation or a peak in motivation in the middle of the rehabilitation period (T1), whereas other patients lose motivation in the second half of the rehabilitation period.

The interviewees clearly conclude that their motivation is influenced by different factors. They raise examples such as self-reflection when reporting daily activities in the evening, awareness that their physical activity level was not sufficient which is reinforced by the weekly goal representation (flags to be reached), awareness that the caregivers can monitor their activities via the dashboard between sessions in the rehabilitation centre, motivational conversations with the physiotherapists during SDM session (when looking together at the dashboard) and while they guide exercise training.

The interviews mostly confirm a rather stable motivation in patients over time. A number of patients however mention losing motivation to exercise. Some of these persons fear that they will not continue with sufficient home-based training after the supervised rehabilitation trajectory, which for some of them is a reason to voluntary extend the supervised rehabilitation trajectory. On the contrary, other participants were glad to approach the end of the supervised and app-supported rehabilitation phase, and mention "*I needed the guidance in the beginning, but now I know how to continue at home*".

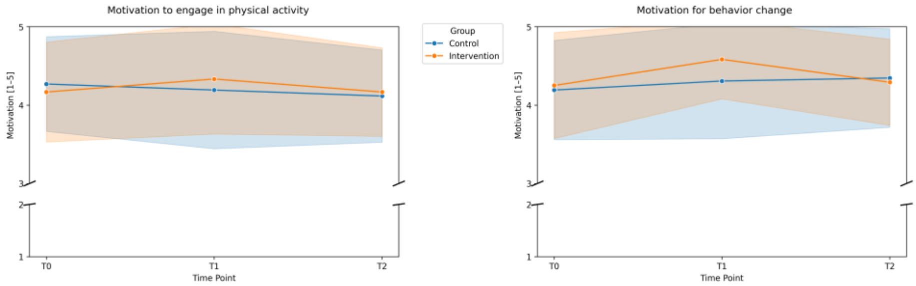

Fig. 7. Motivation to engage in physical activity (left) and motivation for behaviour change (right), for three points in time for the intervention group (n = 28) and the control group (n = 30).

At first sight, the quantitative results on participants' motivation for behaviour change are surprising, even when it was not significant (Mann-Whitney U test, U = 505.5, p = 0.13), as the overall picture seems less positive than the motivation to engage in physical exercise, especially towards the end of the rehabilitation program (see **Fig. 7**). The mixed-methods approach is beneficial, as the participants' remarks contextualise these results. Several persons mention "*I don't want to change my behaviour…I think I'm doing well now and exercise enough, so I want to maintain my behaviour but not change it.*" or express similar opinions.

3.4 Satisfaction

Participants were asked to rate their perception of the overall rehabilitation approach by means of a questionnaire taken at the three main points in time of the SharedHeart study. This questionnaire is taken by both the intervention group and the control group. **Fig. 8** shows that both groups show an evolution over time in their rating of satisfaction about the training program. The satisfaction of the control group tends to stabilise or even decrease in the second half of the rehabilitation period, whereas the satisfaction of the intervention group shows a positive trend till the end of the rehabilitation program (T2). Even with a coincidentally lower average satisfaction for the intervention group than for the control group at the start of the rehabilitation (T0, week 1), the average satisfaction of the intervention group outperforms the satisfaction of the control group after a few weeks and sustains this till T2.

The difference between the delta of the satisfaction levels of the intervention group and the control group (at T2 – at T0) is a statistically significant result (Mann-Whitney U test, $U = 298$, $p = 0.04$).

This result means that the shared decision making approach led to a higher satisfaction on the training program.

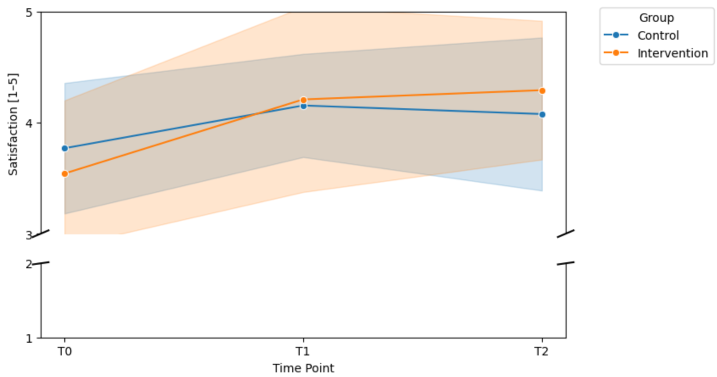

Fig. 8. Satisfaction about the training program for three points in time for the intervention group (n = 28) and the control group (n = 30).

The qualitative information collected in the interviews clarifies that participants attribute the satisfaction on the training program to a variety of reasons. The fact that the training program takes into account the participants' preference for certain physical activities, that were collected at the start of the rehabilitation trajectory, was frequently highlighted in the interviews. The shared decision making encounters, during which the physiotherapist discusses the patient's performance of the previous week (including home-based training reported via the mobile app) and defines the training program for the upcoming weeks, was also strongly appreciated.

3.5 Outcome measures

The intervention group showed a greater improvement in quality of life, peak oxygen uptake and step count over a 12-week intervention, compared to the control group. For detailed results from a medical perspective, we refer to [8].

While searching for the role of the digital tools in the effectiveness of SDM, we decided to perform an extra analysis on the physical activity level. This is expressed as the average daily step count, and was measured in both the control and the intervention group during one week at the start and one week at the end of the study, using a Fitbit Charge device. We were interested at the change in the step count between the start

(T0) and the end of the study (T2), and how this situates with respect to the starting level of physical activity (step count at T0). For this, we perform a Shapiro-Wilk test to check the normality of the groups. As the step counts in the intervention group were not normal distributed, it was decided to use the non-parametric Mann-Whitney U test to determine if there is a difference between the control and intervention groups. Results show that there is a statistically significant difference between both groups of the study ($U = 352$, $p = 0.0057$) for the change in step count. It should be noted that even after removing outliers in this analysis, the significant difference remains ($U = 322$, $p = 0.0070$). Visual inspection of the result for the intervention group (left part of **Fig. 9**) suggests that the SDM approach and possibly the goal setting in the mobile app challenge also persons with a higher starting level to increase their activity level.

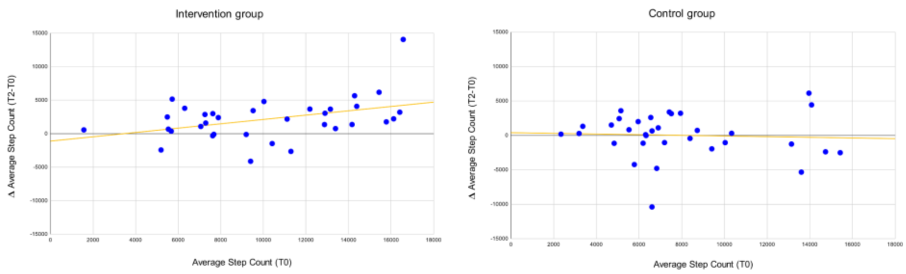

Fig. 9. Change in average daily step count during study (vertical) versus average daily step count at the start of the study. Left: intervention group (n = 34), right: control group (n = 34).

3.6 Correlations

In the previous sections, some highlights of results on essential constructs of our theoretical model were presented. To investigate to what extent our theoretical model is applicable for the impact of SharedHeart mobile app on the rehabilitation trajectory and its outcomes, possibly relevant correlations between the constructs were calculated. **Table 3** shows the numerical results. We refer to the Methods section for an overview of the data items that were used per construct. In **Fig. 10** we revisit the representation of the model with colour coded lines to indicate the correlations. Certain correlations could not be detected for all participants in the intervention group, but was statistically significant for a subgroup, namely those patients that achieved at least 70% adherence to the training program, defined as 70% for both adherence to minimum minutes per week and adherence to recommended number of sessions. It should be emphasised that the existence of a correlation between two constructs does not necessarily indicate a causal relationship.

As indicated in **Fig. 10**, two correlations were specifically found for the subgroup with at least 70% adherence to the training program. There was a moderated correlation between Usage and Motivation for behaviour change ($r = 0.55$, $p < 0.05$) and between Motivation to engage in physical exercise and HeartQoL Physical subscale ($r = 0.56$, $p < 0.05$).

Table 3. Spearman rank-order correlation coefficients for the full participant group (n = 23). For those constructs of the theoretical model for which a correlation was found. (* indicates $p < 0.05$, ** indicates $p < 0.01$)

	Measures	Technology-related			Rehabilitation Process Related					Outcome Related	
		1	2	3	4	5	6	7	8	9	10
1	Usage (SE)	1									
2	Usability	-0.13	1								
3	Usefulness	-0.19	0.75**	1							
4	Motivation Behaviour Change	0.25	0.58**	0.66**	1						
5	Motivation Exercise	0.08	0.67**	0.64**	0.82**	1					
6	Satisfaction	0.15	0.51*	0.37	0.60**	0.82**	1				
7	Adherence (Min/Week)	0.85**	-0.07	-0.12	0.25	0.15	0.16	1			
8	Adherence (Session)	0.78**	0.04	-0.16	0.15	0.11	0.13	0.89**	1		
9	HeartQoL	0.14	0.25	0.47*	0.28	0.32	0.18	0.1	0.18	1	
10	Exercise Capacity	0.28	-0.09	0.02	0.07	0.04	-0.25	0.35	0.46*	0.22	1

4 Discussion

The SharedHeart RCT provided evidence for the effectiveness of shared decision making supported by digital tools in the context of physical activity in cardiac rehabilitation, based on change in quality of life, exercise capacity and level of physical activity measured by average daily steps. In the SharedHeart study, the SDM in the intervention group was implemented as a hybrid trajectory with a mobile app to self-manage home-based training, and SDM encounters in addition to regular centre-based exercise sessions. This study design does not clearly reveal what component(s) of the SDM intervention determine its successful application. Therefore, we performed a secondary analysis from a multidisciplinary perspective, with a focus on HCI-related aspects and with attention for the role of the digital technology.

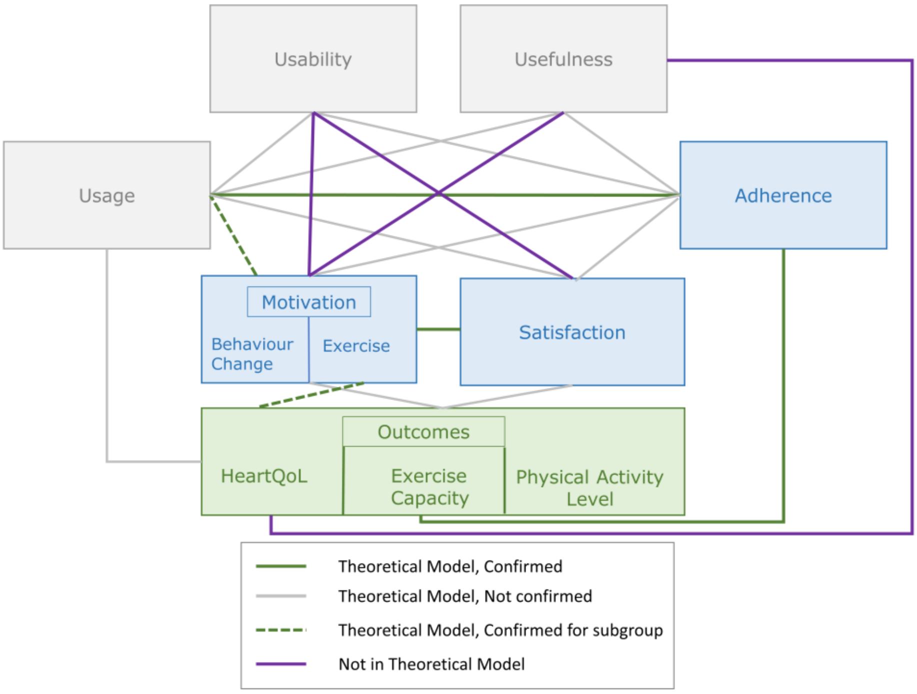

Fig. 10. Confirmed and hypothesised correlations are colour coded in a more detailed version of the model introduced in figure 1. The subgroup are those participants with at least 70% adherence to the training program, defined as 70% for both adherence to minimum minutes per week and adherence to recommended number of sessions. Total participants in analysis n = 23, subgroup n = 13.

To this aim, we constructed a theoretical model to visualise the – hypothesised - correlations between relevant constructs that relate to (1) technology (usability, usefulness and usage of the mobile app), (2) to the rehabilitation process (motivation to exercise, motivation for behaviour change, satisfaction and adherence), and (3) to health-related outcomes (quality of life, exercise capacity and amount of physical activity).

4.1 Summary of the findings

Next to highlighting interesting results for a selection of individual concepts, (1) usability and usage, (2) adherence to the training program, (3) motivation, (4) satisfaction of the patients with the rehabilitation approach and (5) outcomes such as physical activity level, we reported on detected correlations between constructs. Perceived technology-related qualities such as ease of use, ease of understanding and usefulness of the app seem to directly influence rehabilitation process related concepts such as the patients' motivation for the training program and their overall satisfaction about the rehabilitation trajectory. Our study confirms that shared decision making leads to higher satisfaction about the rehabilitation trajectory, as previously reported in literature [7], [10], [19].

We found that higher adherence to the guideline-based exercise program leads to better exercise capacity, which was expected because the EXPERT exercise prescriptions [11], [12] are based on ESC guidelines and expert opinions. By comparison with the control group we notice that the mobile app might stimulate persons with a higher starting level in terms of average daily step count to push their limits.

Our former RCT revealed already that the shared decision making approach, supported by the SharedHeart applications, led to improved health-related quality of life (HeartQoL) which was the primary outcome of the study. The secondary analysis presented here adds to this result that perceived usefulness of the digital tools directly correlates to health-related quality of life. This is consistent with the findings in other studies offering hybrid interventions (centre-based in combination with home-based rehabilitation) such as [5], which makes us believe that the digital tools for use at home (SharedHeart mobile app) and during SDM encounters (dashboard) also contribute to the quality of life by providing appreciated support for the patients' rehabilitation.

4.2 Design implications for applications supporting SDM

While the quantitative RCT results were very important to demonstrate the effectiveness of the digitally-supported shared decision making approach, the secondary analysis contributed to some extent to find clarifications. Not all hypotheses were confirmed, and the qualitative data from the interviews could not explain all results. Nevertheless, the mixed-methods approach has been extremely beneficial to put things in context, and discover the participants' integral story beyond the data.

The theoretical model, that we constructed to visualise a set of hypotheses, explicitly reminds us that constructs and events are interrelated. The success of the SDM rehabilitation trajectory, and the patient's well-being throughout this journey, is a complex combination of factors. Given our interest in the role and contribution of digital applications to the effectiveness of an SDM approach, it is no surprise that we compiled the initial theoretical model with constructs from the perspective of both technology and the rehabilitation process, and tried to find their mutual relations and influence on the outcome measures. Even if a number of correlations turned out to be statistically significant and thus confirmed the underlying hypothesis, the theoretical model is subject to future improvements.

The ultimate goal of this research is to deduce insights that can be used in future studies and more specifically in the design of future SDM supporting applications. This study confirms the importance of traditional quality criteria for digital applications such as usability and perceived usefulness, because of their obvious impact on the patient's overall satisfaction and motivation for the rehabilitation trajectory that possibly implies behaviour change. A key component that came up during the analysis is "personalisation". Quantitative data (e.g., from diverse ad hoc questionnaires) and qualitative data emphasise the importance of collecting patient preferences for physical exercise, but also to design the applications in such a way that they can accommodate a variety of individual rehabilitation trajectories. Indeed, participants stressed the need for flexible planning of physical activity and structured exercise in the rehabilitation program supported by the digital tools. When asked what modules of the SharedHeart applications motivated them most, there were a few favourites but participants named a variety of options. Similar to its use in our previous studies, patients appreciate a lot the flags representation of the weekly exercise goals and the progress bars. But they also made clear that they are not interested in checking the history of their exercise in the calendar-like month widget, and would prefer to see a more general view on evolution over time in the app, comparable to representation in the dashboard that is based on progress bars. This last example also shows that participants had a strong opinion on what features of the dashboard facilitated their SDM encounter with the cardiologist or physiotherapist.

4.3 Limitations and future work

A limitation of the study is the lower availability of data for the control group: no qualitative data from interviews, and no trustworthy reporting of exercise throughout the study. Only paper diaries for week 1 and week 12 of the study were completed by a minority of the subjects, and suffered from a lot of missing data. Despite possible bias caused by self-reporting of physical activity in the intervention group, more complete data is available for this group. Furthermore, it is beyond the scope of this article to extensively report all results achieved by analysing the quantitative and qualitative data that were collected in the study. We focused on the role of the mobile app. The impact of the dashboard, of the patient-caregiver interaction during the SDM encounters, and of the supervised centre-based training sessions is not fully investigated, thus leaving these likely contributors to the effectiveness of the shared decision making underexposed. It is very likely though, that these indirectly contribute to the participants' perception on rehabilitation, e.g., motivation and satisfaction. Also, in the scope of this paper we mainly used the qualitative data from the interviews to contextualise findings, but these data remain underexploited to strengthen the rationale for SDM success. These additional data from the SharedHeart study could inspire us in future research to elaborate and fine-tune the theoretical model we presented in this paper to frame our secondary analysis. Similarly, more advanced statistical approaches could be instrumental in search for causal relationships between relevant technology-related or rehabilitation process related concepts and effective improvement of outcomes of the rehabilitation by means of shared decision making.

5 Conclusion

As a follow-up of interesting results of an RCT with a digitally supported shared decision making approach on physical activity, a secondary analysis was presented in this paper. In search for deeper insights in what components and characteristics of the SDM make it outperform the standard centre-based training, we investigate a number of constructs related to the digital applications, the rehabilitation process and outcomes of the RCT. While not all expected correlations between the constructs are confirmed, the gained insights are beneficial for future design of digitally supported SDM interventions.

6 Acknowledgements

The design and development of the SharedHeart concept and applications were supported by BOF18DOC26 (UHasselt Special Research Fund). The usability study, the RCT and the presented secondary analysis were subsidised by H2020 CoroPrevention (grant nr. 848056). An FWO International Coordination Action "the EXPERT network" (G0F4220N, G0ADQ24N) supports maintenance of the exercise prescription algorithm of the EXPERT tool.

7 References

1. F. L. J. Visseren et al., "2021 ESC Guidelines on cardiovascular disease prevention in clinical practice.," Eur. Heart J., vol. 42, no. 34, pp. 3227–3337, Sep. 2021, doi: 10.1093/eurheartj/ehab484.
2. R. S. Taylor, H. M. Dalal, and S. T. J. McDonagh, "The role of cardiac rehabilitation in improving cardiovascular outcomes," Nat. Rev. Cardiol., vol. 19, no. 3, pp. 180–194, 2022, doi: 10.1038/s41569-021-00611-7.
3. J. J. Su, D. S. F. Yu, and J. T. Paguio, "Effect of eHealth cardiac rehabilitation on health outcomes of coronary heart disease patients: A systematic review and meta-analysis," J. Adv. Nurs., vol. 76, no. 3, pp. 754–772, 2020, doi: 10.1111/jan.14272.
4. M. Scherrenberg, M. Falter, and P. Dendale, "Cost-effectiveness of cardiac telerehabilitation in coronary artery disease and heart failure patients: Systematic review of randomized controlled trials," Eur. Hear. J. - Digit. Heal., vol. 1, no. 1, pp. 20–29, 2020, doi: 10.1093/ehjdh/ztaa005.
5. P. Eser et al., "Comparison of patient characteristics and health outcomes between self-selected centre-based cardiac rehabilitation and hybrid cardiac telerehabilitation: a prospective cohort study," Eur. J. Prev. Cardiol., p. zwaf107, 2025, doi: 10.1093/eurjpc/zwaf107.
6. K. Coninx and D. Hansen, "Self-selected cardiac rehabilitation trajectories: increasing patient empowerment," Eur. J. Prev. Cardiol., p. zwaf283, May 2025, doi: 10.1093/eurjpc/zwaf283.
7. Y. Bombard et al., "Engaging patients to improve quality of care: a systematic review.," Implement. Sci., vol. 13, no. 1, p. 98, Jul. 2018, doi: 10.1186/s13012-018-0784-z.
8. S. E. Kizilkilic et al., "A Digitally-Supported Shared Decision Making Approach for Patients during Cardiac Rehabilitation: a Randomized Controlled Trial," Eur. J. Prev. Cardiol., p. zwaf537, Aug. 2025, doi: 10.1093/eurjpc/zwaf537.
9. "HeartQoL." Accessed: Sep. 02, 2025. [Online]. Available: https://www.escardio.org/Education/Practice-Tools/CVD-prevention-toolbox/HeartQoL
10. P. K. Narapaka, S. Kaduburu, R. Obulapuram, M. Singh, and K. Murti, "A systematic literature review and meta-analysis of randomized control trials on the influence of shared decision-making as intervention on patients' satisfaction among mental healthcare," J. Public Health (Bangkok)., 2024, doi: 10.1007/s10389-024-02354-4.
11. D. Hansen, K. Coninx, and P. Dendale, "The EAPC EXPERT tool.," Eur. Heart J., vol. 38, no. 30, pp. 2318–2320, Aug. 2017, doi: 10.1093/eurheartj/ehx396.

12. D. Hansen et al., “The European Association of Preventive Cardiology Exercise Prescription in Everyday Practice and Rehabilitative Training (EXPERT) tool: A digital training and decision support system for optimized exercise prescription in cardiovascular disease. Concept, definitions and construction methodology.,” Eur. J. Prev. Cardiol., vol. 24, no. 10, pp. 1017–1031, Jul. 2017, doi: 10.1177/2047487317702042.
13. L. Donkin, H. Christensen, S. L. Naismith, B. Neal, I. B. Hickie, and N. Glozier, “A systematic review of the impact of adherence on the effectiveness of e-therapies,” J. Med. Internet Res., vol. 13, no. 3, pp. 1–12, 2011, doi: 10.2196/jmir.1772.
14. F. D. Davis, “Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology,” MIS Q., vol. 13, pp. 319–340, 1989, [Online]. Available: https://api.semanticscholar.org/CorpusID:12476939
15. V. Venkatesh, M. G. Morris, G. B. Davis, and F. D. Davis, “User Acceptance of Information Technology: Toward a Unified View,” Institutions \& Transit. Econ. Microecon. Issues eJournal, 2003, [Online]. Available: https://api.semanticscholar.org/CorpusID:14435677
16. E. Orruño, M. P. Gagnon, J. Asua, and A. Ben Abdeljelil, “Evaluation of teledermatology adoption by health-care professionals using a modified Technology Acceptance Model.,” J. Telemed. Telecare, vol. 17, no. 6, pp. 303–307, 2011, doi: 10.1258/jtt.2011.101101.
17. Y.-E. Park et al., “User Experience and Extended Technology Acceptance Model in Commercial Health Care App Usage Among Patients With Cancer: Mixed Methods Study,” J Med Internet Res, vol. 26, p. e55176, Dec. 2024, doi: 10.2196/55176.
18. C. Bonneux, D. Hansen, P. Dendale, and K. Coninx, “The SharedHeart Approach: Technology-Supported Shared Decision Making to Increase Physical Activity in Cardiac Patients,” in Pervasive Computing Technologies for Healthcare, H. Lewy and R. Barkan, Eds., Cham: Springer International Publishing, 2022, pp. 469–488.
19. T. J. Crijns et al., “Moderators and Mediators of the Relationship of Shared Decision-Making and Satisfaction,” J. Patient Exp., vol. 10, pp. 1–8, 2023, doi: 10.1177/23743735231171563.