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Digiphysical Approach in Post-COVID Rehabilitation: Process-Oriented Tool Support and Solution Patterns

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Abstract. Individuals suffering from long-term cognitive impairments following COVID-19 engage in a wide range of activities throughout their cognitive rehabilitation journey. This journey may include diagnostic assessments, therapeutic interventions, administrative coordination, and self-managed rehabilitation tasks. To effectively support and enhance such multifaceted rehabilitation processes, a *digiphysical approach* – which integrates digital and physical components – offers a promising solution. This article presents a process-oriented prototype based on the digiphysical approach, designed to bridge clinical and administrative tasks while combining digital and physical interventions. The article also reports findings from an initial evaluation of the prototype conducted with key rehabilitation professionals as respondents. Furthermore, five reusable solution patterns for implementing digiphysical rehabilitation are presented. These patterns are intended to be applicable not only in the studied context but also to support other care providers and organizations aiming to develop or enhance digiphysical rehabilitation services.
Keywords: Rehabilitation Process, Digiphysical Approach, Digital Healthcare, Process-Oriented Tool, Model-Based Development, Reusable Solution Patterns, Cognitive Impairments, COVID-19.

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1 Introduction

1.1 Background

Digitalization in healthcare enables more efficient resource utilization, personalized treatment pathways, and enhanced patient engagement [1], [2]. Yet, in-person consultations remain pivotal for examinations and treatments. Nevertheless, many of these physical interactions can be complemented with digital tools, resulting in a hybrid approach where digital and physical components work in synergy and reinforce each other – an approach sometimes referred to as "digiphysical care" [3].

While digiphysical care has gained traction in some healthcare domains, its application in rehabilitation remains limited. In particular, digital tools often operate in isolation and lack a structured framework that supports a cohesive and continuous rehabilitation process. To fully harness the potential of digiphysical rehabilitation, there is a need for process-oriented systems and structured approaches that guide how digital and physical interventions interact throughout the rehabilitation process.

In this context, we propose a process-oriented tool supported by a set of solution patterns to structure digiphysical rehabilitation. The tool is designed to coordinate clinical, administrative, and self-managed activities across both digital and physical modalities. The solution patterns applied in the tool guide the coordination between digital and physical elements by addressing common problems, ensuring that the components support the full rehabilitation pathway. By aligning digital interventions with physical rehabilitation tasks, a well-integrated digiphysical IT system can reduce strain on rehabilitation services while enhancing patient self-rehabilitation and continuity of care.

This article draws on a research project conducted between 2021 and 2024, aimed at developing a structured, process-oriented prototype to support cognitive rehabilitation for individuals with long-term cognitive impairments following COVID-19 infection. The prototype integrates physical and digital interventions and was developed in close collaboration with rehabilitation professionals. A process-oriented tool, the Visuera Information Manager, was used for development.

In this article, we present both the process-oriented tool and the created prototype, as well as an evaluation of the prototype's utility, functionality, and usability from the perspective of rehabilitation professionals. We also introduce five solution patterns derived from the project findings, which are intended to guide other care providers seeking to implement or enhance digiphysical rehabilitation services. This work is a continuation of the work presented in [4]; we here focus more on the initial requirements and extract applicable patterns for future implementation of digiphysical care.

1.2 Goal and Research Questions

The overarching goal of the article is to contribute to the conceptualization, design, and evaluation of digiphysical rehabilitation. By integrating process thinking and pattern-based design into a functioning digiphysical care flow prototype, we demonstrate how hybrid care models can be operationalized and reused across care contexts.

To guide our investigation, we formulated the following research questions:

1. How can digiphysical care be applied in rehabilitation?
2. What are the rehabilitation personnel's attitudes towards a digiphysical solution?
3. What solution patterns can support other care providers in developing or enhancing digiphysical rehabilitation services?

The remainder of the article is structured as follows. Section 2 reviews related work relevant to the study. Section 3 outlines the research methodology, while Section 4 describes the context in

which the study was conducted. Section 5 presents the development of a digiphysical care flow prototype using a process-oriented tool that models and supports the rehabilitation process. Section 6 reports findings from the evaluation of the prototype carried out in collaboration with rehabilitation professionals as respondents. In Section 7, five solution patterns are introduced to illustrate how digiphysical rehabilitation can be structured and supported. Finally, Sections 8 and 9 offer a discussion of key insights, conclusions, and suggestions for future research.

2 Related Research

2.1 Digitization, Digitalization and Digital Transformation

Digiphysical care can be viewed as a distinct form of digitization, digitalization, or digital transformation in healthcare. The term "digitization" generally refers to the process of converting analog information into digital form. In contrast, "digitalization" refers to the integration of digital technologies into an organization's processes or services to improve efficiency and service quality. Moreover, "Digital transformation" denotes a more fundamental organizational change, reshaping structures, processes, and culture to create value and foster innovation in healthcare and beyond [5], [6]. As such, digital transformation is a more complex and multifaceted process than digitalization [5], [6]. Digiphysical care differs from these concepts by specifically focusing on the seamless and synergistic integration of digital and physical healthcare components throughout the care process rather than solely on the technological conversion of analog information, process efficiency, or organizational transformation.

Despite ambitious goals, the implementation of digital solutions in healthcare has fallen short of expectations across the EU. This shortfall reflects broader challenges in the sector, including the complexity of healthcare systems, conflicting stakeholder interests, and bureaucratic obstacles that have hindered progress [7]. Technologies such as AI have yet to make an impact on the broader management of healthcare processes [8]. To enhance collaboration and overcome barriers to both digitalization and digital transformation, changes in technology, workflows, decision-making processes, and organizational mindsets are needed [9].

2.2 Process-Oriented Care

In this article, we present a digiphysical care flow prototype built using a process-oriented tool to support and drive the rehabilitation process. A large body of research on process-oriented care highlights the decisive role of leadership and an adaptive organizational culture in facilitating change toward process orientation in healthcare. However, traditional function-based hospital structures often hinder this process-oriented transition [10]. More recent studies on Lean Six Sigma emphasize its positive impact on process efficiency and service quality but also highlight a critical gap: the lack of long-term sustainability strategies for such approaches [11]–[13].

2.3 Digiphysical Care

Although the term *digiphysical care* is not yet widely adopted in academic literature, a few studies and official reports have begun to explore its potential. Entezarjou et al. investigated healthcare utilization following digiphysical assessments compared to traditional in-person consultations for infectious symptoms in Swedish primary care [14]. In this model, patients first complete an eVisit and are referred to a physical consultation only when necessary. The study found that the majority of eVisit patients (69%) did not require a follow-up physical visit and that healthcare utilization over two weeks was comparable to that of patients managed through traditional office visits once those needing urgent care were accounted for. These findings suggest that digiphysical models can

serve as efficient alternatives for managing low-complexity conditions, especially when protocols are in place for triaging patients between digital and physical care.

In a more advanced application, Kastengren et al. evaluated Sweden's first *digiphysical hospital-at-home* care model, offering 24/7 high-acuity virtual inpatient care combined with physical home visits by medical staff [15]. The study demonstrated high levels of patient satisfaction, low rates of complications, and safe substitution of hospital stays for acute medical conditions. This shows that digiphysical care is not limited to primary care or low-complexity needs but can be extended to high-acuity contexts through coordinated hybrid infrastructures.

In the Swedish policy landscape, the government-commissioned report *SOU 2019:42* [16] proposed a system-wide reform toward *integrated digiphysical care* to improve accessibility and continuity in primary care. One of the key ideas was to allow patients to select a single provider responsible for both digital and physical appointments, thereby enhancing continuity and reducing fragmentation. Drawing on experiences from the NHS in England, the report also emphasized the need for updated reimbursement systems and governance models to support cohesive care pathways across modalities.

While research has demonstrated feasibility in both low- and high-acuity settings, there remains a lack of process-oriented tools and structured models to support digiphysical rehabilitation – especially for patients with complex or long-term needs, such as those with cognitive impairments following COVID-19. The present study seeks to address this gap by proposing a structured approach grounded in process thinking.

In this article, *digiphysical care* or *digiphysical rehabilitation* refers to a hybrid approach in which digital and physical components work in synergy and reinforce one another. This integration can occur at the process level, where entire care processes involve both digital and physical activities, or at the activity level, where a single task includes elements of both. For instance, a rehabilitation professional may use digital tools – such as assessment software or remote monitoring devices – while conducting an in-person examination or treatment session. The digiphysical approach thus enables more seamless and coordinated care by blending modalities within and across activities.

2.4 Pattern-Oriented Thinking

In this article, we also introduce a set of solution patterns. While explicit use of solution patterns in digiphysical rehabilitation is still limited, pattern-oriented thinking is well established in neighboring domains. Patterns are structured, reusable representations of knowledge that offer standardized solutions to recurring problems. Originating in architecture [17] and software engineering [18], the concept has since influenced fields such as user interface design [19] and collaborative learning [20]. In healthcare and service design, similar pattern approaches have been applied to process modeling [21], process architecture [22], and e-health innovation [23].

One such approach in healthcare is the use of process variability patterns, which offer modular, semi-formal visual representations of alternative workflows in clinical settings [21]. These patterns were derived from empirical analysis of over 140 process descriptions, guidelines, and action cards, and include archetypes such as *Pass All Tests*, *Optional*, and *Process Checklist*. In a similar vein, this article documents solution patterns that support the design and implementation of digiphysical systems.

3 Research Methodology

3.1 Research Strategy: Action Research

In the project presented in this article, a structured, digiphysical care flow prototype was developed to support cognitive rehabilitation for individuals experiencing long-term impairments following COVID-19 infection. The work was grounded in the research strategy *action research*, well-suited

to applied healthcare technology initiatives. Action research, as conceptualized by [24], involves iterative cycles of planning, acting, observing, and reflecting – an approach that aligns with the project's dual aims: to improve rehabilitation practices in real-world settings and to generate generalizable, research-based insights.

The project was carried out between 2021 and 2024 by a cross-disciplinary team of system developers, healthcare professionals, and academic researchers. Collaboration was maintained through monthly focus group sessions – via Zoom due to pandemic-related constraints. This constellation enabled the integration of technical, clinical, and administrative perspectives at all stages of development.

The digiphysical care flow prototype evolved incrementally over time, structured through a series of action research cycles:

- *Mapping of selected activities and resources (planning).* In each cycle, a specific segment of the rehabilitation process was examined collaboratively by clinicians, administrative staff, researchers, and developers. Focus group sessions served as a forum for mapping key activities, identifying resource use, and discussing everyday challenges in the rehabilitation process. The sessions – recorded and transcribed – provided a structured foundation for identifying needs and informed the stepwise refinement of the prototype.
- *Co-design of potential solutions (acting).* Building on insights from the mapping phase, potential solutions – such as digital functions, process adaptations, and interface elements – were proposed and iteratively refined. These co-design activities were carried out in follow-up focus group sessions – enabling a continuous dialogue between clinical and administrative realities and system design.
- *Implementation of selected solutions (acting).* Prioritized ideas were realized through the development of process models, message flows, and user interface components integrated into the prototype.
- *Demonstration and validation (observing).* Newly implemented features were presented to stakeholders in subsequent focus group sessions, allowing for hands-on testing and collaborative assessment of their relevance, usability, and alignment with practice.
- *Feedback integration (reflecting).* Input from stakeholders was fed into the next cycle, ensuring that both technical and process-related aspects evolved in response to real-world needs.

3.2 Summative Evaluation

To assess the process-oriented tool and the resulting digiphysical care flow prototype after the conclusion of the development cycles, a summative evaluation was conducted in the form of a group interview. The interview included four rehabilitation professionals from the Post-COVID Clinic at the Department of Rehabilitation Medicine, Danderyd University Hospital. Notably, these participants had not been involved in the earlier development process, providing an "external" perspective on the prototype. The group consisted of a physician, a psychologist, and two occupational therapists. The purpose of this evaluation was to gain insights into the perceived usefulness, usability, and applicability of the prototype in real clinical practice.

The 60-minute group interview was structured into three distinct phases:

1. Presentation of the process-oriented tool, the created digiphysical care flow prototype, and the vision treatment process (see Table 2 for this process) (10 minutes).
2. Demonstration of interface screenshots showcasing system functionality (15 minutes).
3. Moderated discussion guided by a semi-structured interview protocol covering four thematic sections; see below (35 minutes).

The interview protocol was designed to explore user experiences and perceptions across the following four thematic sections:

- General perception of the tool and the digiphysical care flow prototype: This section captures users' overall impressions, perceived advantages and disadvantages, and suggestions for improvement.
- Expectations and attitudes: Participants are asked whether the prototype meets their expectations and whether they believe they could become confident users after a period of use.
- Needs, usefulness, and functionality: This part investigates whether the prototype supports the users' practical needs in clinical and administrative routines. It also explores which functions are most beneficial, why they are valuable, and what functionalities are lacking in the current version.
- Usability: Participants are invited to reflect on the prototype's ease of use, any perceived difficulties, and the knowledge required for independent use. The navigation system is also evaluated, especially the ability to move between tasks and return to the main menu.

The group interview was recorded, transcribed, and analyzed using thematic analyses [25].

3.3 Developing Digiphysical Rehabilitation Patterns

In addition, five digiphysical rehabilitation patterns were developed (presented in Section 7). These patterns emerged inductively through the iterative action research cycles. Rather than being pre-defined, these patterns crystallized from real-world challenges encountered during development and from the practical solutions co-designed with stakeholders. Each pattern represents a reusable, generalizable design element that encapsulates a successful way of addressing recurring needs in the digiphysical rehabilitation process.

This part of the research can be viewed as a process of knowledge generation, in which situated experiences were abstracted into transferable design insights. The resulting patterns not only informed the final digiphysical care flow prototype but also provided a conceptual toolkit for future projects aiming to develop or improve rehabilitation technologies that combine physical and digital modalities. In this way, the project contributes not only a working prototype but also a set of scalable design principles that can inspire innovation in broader contexts of technology-supported care.

The development of unevaluated solution patterns represents a minor departure from the typical action research cycle, where evaluation is typically embedded within the observing and reflecting phases. However, the approach still aligns with the broader goal of generating transferable research knowledge.

Ethical approval for the study was obtained from the Swedish Ethical Review Authority (Dnr 2023-05175-01).

4 The Research Project

4.1 Clinical Background

As presented earlier, the research project in focus in this article was conducted between 2021 and 2024. The project addresses the challenge of designing a digiphysical care flow prototype of a digital rehabilitation process, assisting rehabilitation professionals in effectively managing the whole rehabilitation process and enabling patients to engage in self-rehabilitation with professional support.

The clinical background of the project was the growing number of individuals struggling with persistent cognitive and visual impairments after a COVID-19 infection [26]. When these symptoms persist beyond 12 weeks post-infection, the condition is classified as Post-COVID-19 Condition (PCC) [27]. Patients with PCC commonly experience cognitive dysfunction, fatigue, and, in some cases, visual disturbances [28]. International research efforts continue to explore the

underlying mechanisms linking COVID-19 to these prolonged cognitive symptoms (see, for instance, [29]).

4.2 Digital Rehabilitation Applications

While digital rehabilitation applications exist for cognitive impairments resulting from acquired brain injuries, they are not specifically tailored to address cognitive dysfunction in PCC patients. Moreover, these applications often cover only specific aspects of the rehabilitation process. For instance, *eRehabCog* is a digital rehabilitation application designed for individuals recovering from brain injuries [30]. It offers a structured 12-week remote education program to enhance patients' understanding of neurological impairments and support behavioral changes to improve daily life. Similarly, *Cogmed* is a cognitive training application primarily used to improve working memory and attention in conditions such as ADHD and acquired brain injuries [31]. Although some of its modules could benefit PCC patients, it has not been specifically adapted for post-COVID-19 cognitive rehabilitation.

In response to the growing need for a more comprehensive rehabilitation approach, *eRehabCog* was partially modified in 2023 by the Department of Rehabilitation Medicine in Stockholm (DRMS) at Danderyd University Hospital to accommodate better patients experiencing cognitive impairments following COVID-19 infection. However, no existing tool fully supports the entire rehabilitation process for PCC patients.

4.3 Requirement on the Digiphysical Care Flow Prototype

Prior to the project presented in this article, several IT system support requirements were identified to enhance cognitive rehabilitation for individuals with PCC. These were documented in [32]. Moreover, a key consideration at DRMS was the high prevalence of vision-related issues among PCC patients [33], which resemble those observed in individuals recovering from brain injuries [35]. Since vision therapy is not incorporated in *eRehabCog* or *Cogmed*, requirements were developed after interviews with previous patients and rehabilitation personnel in an earlier research project. However, these requirements were only documented as internal notes. Both these two groups of requirements elicited before the project are summarized in Table 1. These requirements were not specifically developed with a process-oriented or digiphysical approach in mind.

Table 1. Pre-Identified System Support Requirements

Requirement Area	Description	Source
Remote Patient Monitoring	Capability to track patient training activities and outcomes remotely.	DRMS Project [12]
Secure Communication	Chat function to facilitate communication between patients and healthcare professionals.	DRMS Project [12]
Adaptive Training Plans	Ability to customize training intensity and frequency based on individual patient needs.	DRMS Project [12]
Progress Feedback	Providing patients with feedback to regulate training intensity and monitor progress.	Internal Vision Rehab Report
Long-Term Support	Enabling extended follow-up and sustained engagement over time.	Internal Vision Rehab Report
Clinical Oversight	Oversee training methods, assign and monitor training, and plan progression or discharge.	Internal Vision Rehab Report

In contrast, the project presented in this article adopted a process-oriented and digiphysical approach, focusing on the entire rehabilitation process and the activities of various stakeholders. Consequently, the requirements for the digiphysical care flow prototype emerged dynamically through iterative action research cycles involving close collaboration among healthcare professionals, researchers, modelers, and system developers. Early in the project, the following key activities were identified from the patient and professional perspectives:

From the patient perspective –

- Managing appointments and preparing for clinical visits.
- Completing assessment forms prior to visits.
- Engaging in self-rehabilitation exercises.
- Receiving feedback on training progress.
- Accessing long-term follow-up and support.

From the professional perspective –

- Managing referrals and patient intake.
- Coordinating multidisciplinary team meetings.
- Distributing and processing digital assessment forms.
- Monitoring patient progress over time.
- Overseeing training assignments and planning progression or discharge.
- Double entry of data.

These activities were translated into functional requirements during the development process. While the digiphysical care flow prototype was developed as a standalone system, it has been designed with future integration in mind and supported by the process-oriented tool. Specifically, it could be linked with existing applications such as eRehabCog and Cogmed, allowing professionals and patients to access selected functions from these applications directly through the prototype's interface. This potential integration aims to enhance continuity, interoperability, and resource efficiency in cognitive rehabilitation workflows.

5 The Prototype and the Process-Oriented Tool

5.1 The Process-Oriented Tool

In the project, the process-oriented tool Visuera Information Manager was utilized. This tool provides model-based functions for modeling, executing, and integrating processes across various external systems. Built on functions from integration technologies such as Enterprise Application Integration (EAI) engines and Business Process Management (BPM) systems, Visuera Information Manager enables a process-based view of building systems and allows for the integration of a wide range of systems. More information about the tool is available at its website[†] and in sources [35]–[37].

The tool provides a platform that supports rapid model-driven design, implementation, and execution of healthcare processes. Its focus on models and the design of user interfaces and employing a no-code approach allows healthcare professionals to actively participate in all development phases. As a web-based system, it enables efficient creation and modification of user interfaces and process workflows without requiring programming, significantly reducing resource demands compared to conventional development tools.

[†] www.visuera.com

5.2 The Prototype

The process-oriented development tool Visuera Information Manager was used to develop the digiphysical care flow prototype to represent and support the rehabilitation process. First, a process overview model (Figure 1) was created in the tool during the design phase to structure the application. Since the tool is process-oriented, this model presents the application components as processes and sub-processes. It visually maps out how these processes interconnect and interact with each other. Users can access any sub-process from the overview model to design the sub-process further. Once completed, this detailed design of the sub-processes (Figure 2) serves as the basis for the execution of these processes within the tool's runtime environment.

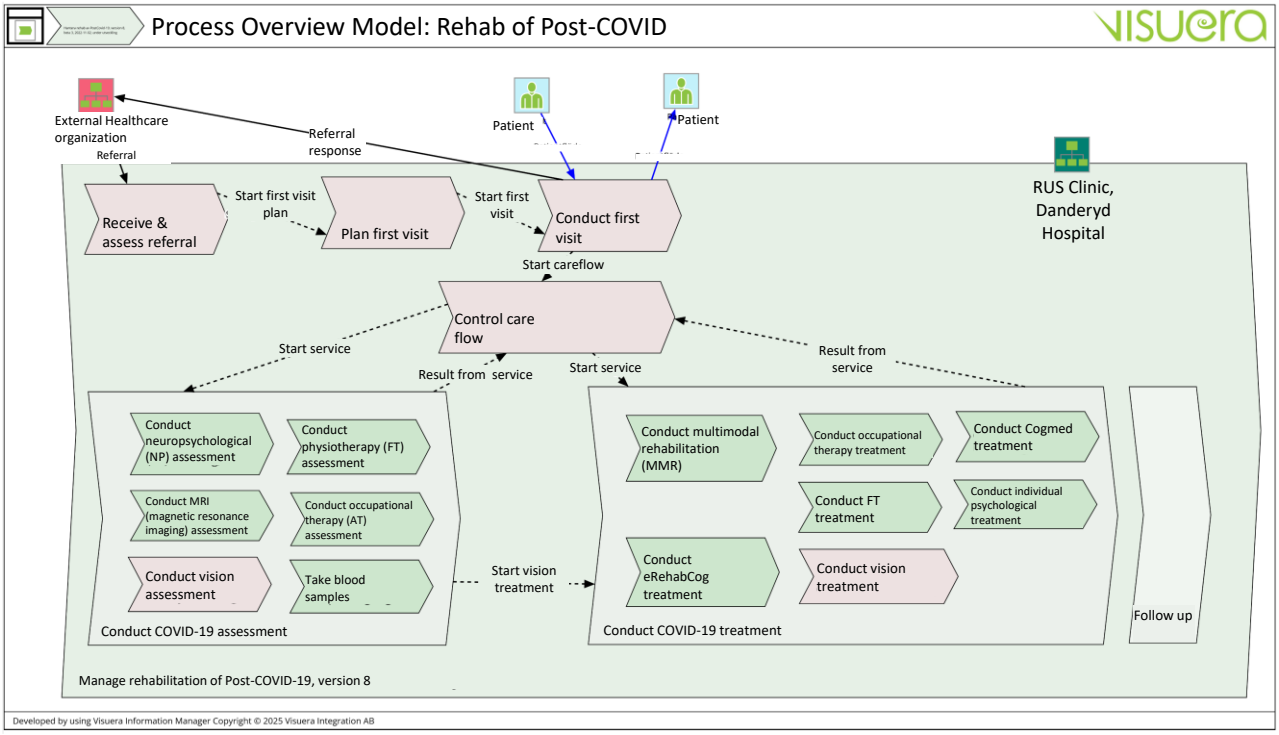

Figure 1. Process overview model

The process-based modeling approach (Figure 2) integrates the following components: the various roles, digital interactions via user interfaces, physical engagements, and electronic process activities. At the system's core is the e-process, which consists of automated tasks triggered by user input through the user interfaces. These activities are also linked to external information sources, including third-party systems, documents, and case-specific data. Consequently, this process-driven approach ensures the coordination of manual, automated, and information-driven workflows within the digiphysical care flow prototype.

One key advantage of this tool in healthcare settings is its seamless integration of digital and physical interactions. Since both automated and manual activities are represented in the process model, the tool can facilitate patient-provider engagements, including in-person visits, virtual consultations, and hybrid (digiphysical) interactions.

The overarching process-based model is similar to the Business Process Model and Notation (BPMN) language. However, unlike BPMN, this model allows for both a horizontal representation of process flow and a vertical representation of role interactions and information sources (Figure 2). During execution, the platform dynamically controls the visibility of user interfaces based on roles and determines data exchanges between users and integrated systems. The tool also stores the states of the process, enabling future playback of each process instance.

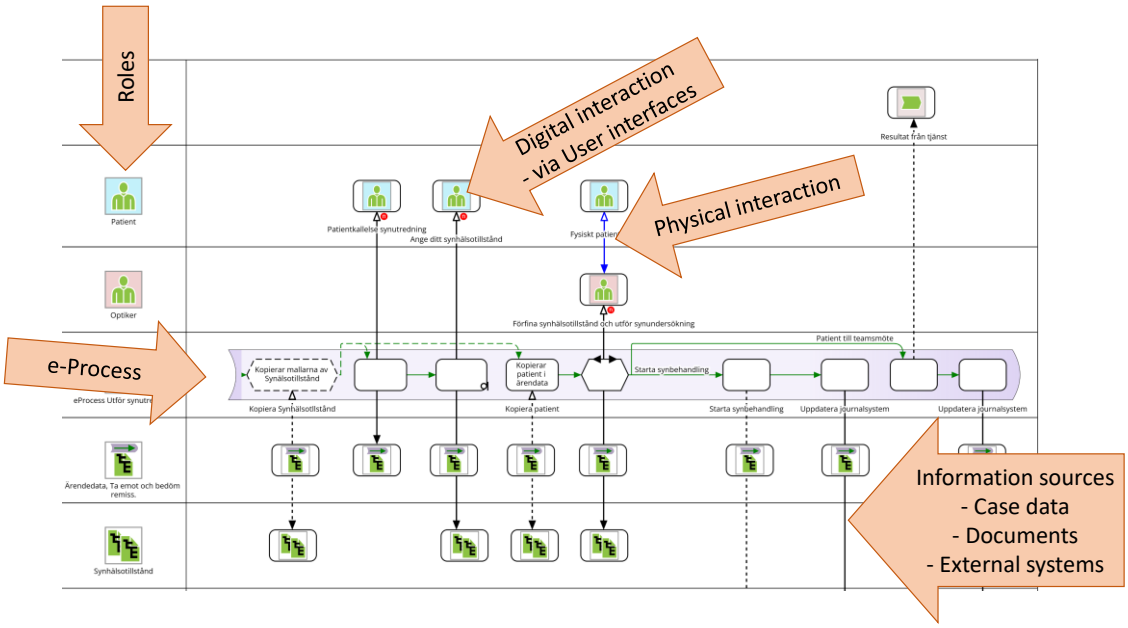

Figure 2. A fragment of the detailed process model created for the rehab process

Each user interface activity depicted in the model allows the design of a corresponding interface screen. Figure 3 illustrates such an interface screen using a form-based design. The prototype includes multiple processes and sub-processes, each associated with several user interfaces.

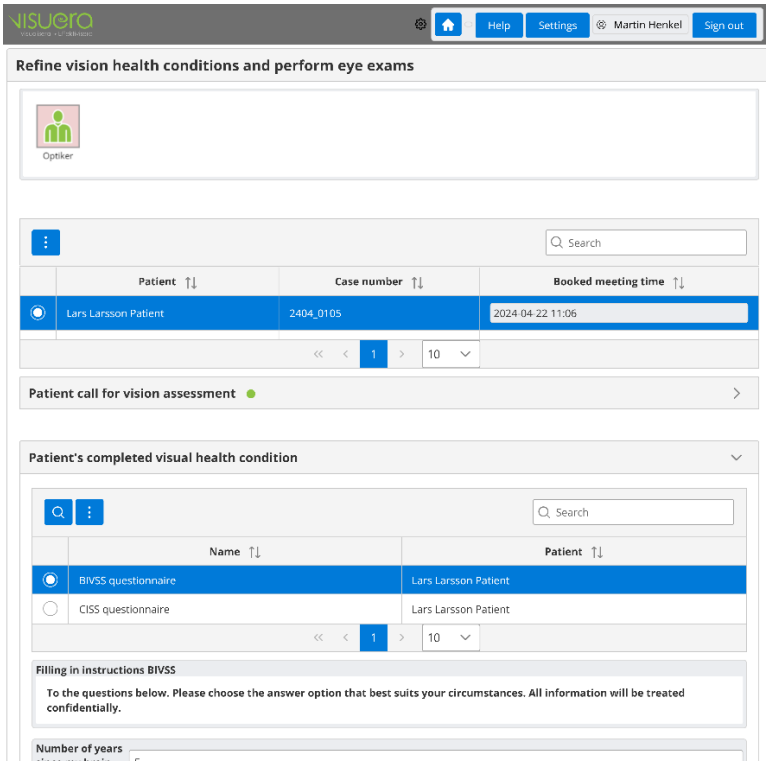

Figure 3. An example of a user interface from the prototype

5.3 The Vision Treatment Process

To highlight the prototype's functionalities, Table 2 presents a subprocess in the digiphysical care flow prototype: the vision treatment process. This process aims to support rehabilitating PCC patients experiencing vision-related difficulties and has been adapted for integration with the

prototype. It is important to note that the process described in Table 2 does not fully represent current medical practices, as the prototype is not yet in clinical use.

Table 2. Vision treatment process adapted to be supported by the prototype

Treatment personnel activities	**Patient activities**
Before the first visit: Create and send an "appointment notice" to a patient for a "vision examination visit", and request the patient to carry out a "visual health condition self-assessment" before the visit (digital, using the prototype)	***Before the first visit:*** Read the "appointment notice" for the "vision examination visit" (digital, using the prototype)
	Before the first visit: Carry out a "visual health condition self-assessment" as preparation for the first visit (digital, using the prototype)
	Before the first visit: Travel to the clinic (physical)
During the first visit: The optometrist and the patient discuss the "visual health condition self-assessment" that the patient has carried out before the visit, and they may refine the answers based on the discussion. After that, the optometrist carries out a physical "vision examination" of the patient. The result of the "vision examination" is recorded in the prototype (digital and physical = digiphysical)	
After the first visit: Create the "vision treatment exercises" for the patient's home-based self-rehabilitation - a first draft (digital, using the prototype)	
Before the second visit: Create and send an "appointment notice" to the patient for a "vision treatment visit" (digital, using the prototype)	***Before the second visit:*** Read the "appointment notice" for the "vision treatment visit" (digital, using the prototype)
	Before the second visit: Travel to the clinic (physical)
During the second visit: The optometrist shows the patient the created "vision treatment exercises for self-rehabilitation" in the prototype. Together, they refine it, if needed (digital and physical = digiphysical)	
	After the second visit: Conduct "vision treatment exercises for self-rehabilitation" at home, and, document the experience by making "self-assessment notes" (digiphysical, carry out physical exercises, and document experiences of the exercises using the prototype as self-assessment notes in the prototype)
At any time: Eventually, send "patient reminder" about conducting "vision treatment exercises for self-rehabilitation" (digital, using the prototype)	***If reminded:*** Read "patient reminder" (digital, using the prototype)
At any time: Check the "vision treatment result of the self-rehabilitation" and patient's "self-assessment notes", and eventually modify the "vision treatment exercises for self-rehabilitation" (digital, using the prototype)	***If modified:*** Read info about the modified "vision treatment exercises for self-rehabilitation" (digital, using the prototype)
Before third visit: Create and send an "appointment notice" for a "vision treatment follow-up visit" (digital, using the prototype)	***Before the third visit:*** Read the "appointment notice" for the "vision treatment follow-up visit" (digital, using the prototype)
During the third visit: "Vision examination follow-up" is carried out, either as a physical or digiphysical visit between a patient and an optometrist (digital or physical)	
After the third visit: Create and send an "analysis of vision treatment of self-assessment" after the "vision examination follow-up visit" (digital, using the prototype)	***After the third visit:*** Read "analysis of vision treatment of self-assessment" (digital, using the prototype)
Digital at any time: Use the chat	

In this process, a patient undergoes an optometric examination, followed by therapy if necessary. For instance, a prescribed therapy might focus on enhancing eye coordination and focus, such as the Brock String Exercise.

As indicated in Table 2, the prototype accommodates various activity types, including physical, digital, and digiphysical interactions. It also supports both clinical and administrative tasks. A clinical task might involve a “vision examination”, whereas an administrative task could entail “carry out scheduling” and “sending appointment notice”. Some functions, such as a chat feature, are designed to provide flexibility, allowing users to engage with them anytime.

6 Initial Evaluation

As mentioned earlier, the initial evaluation was carried out in the form of a group interview with four rehabilitation professionals at the post-COVID Clinic at DRMS (a physician, a psychologist, and two occupational therapists). The discussion was guided by a set of questions concerning the general perception, attitudes, utility, and usability of the digiphysical care flow prototype and tool. It is important to note that the concept of digiphysical care was not introduced to the rehabilitation professionals during the evaluation. The results of the analysis are presented in the following subsections.

6.1 General Perceptions

The professionals expressed a generally positive outlook on the digiphysical care flow prototype, highlighting several advantages. To start with, they appreciated the ability of patients to perform exercises at home and found the prototype’s structured approach to treatment beneficial, allowing for modifications based on patient feedback and progress. The clarity of the exercises and the personalization options were also noted as strong points, enabling tailored activities and notes on the progress.

However, concerns were raised regarding the tool’s applicability across all types of treatments. Some rehabilitation activities require in-person or group settings, making the tool more suitable as a complementary resource rather than a one-fits-all solution. Suggestions for improvement included integrating multiple treatment packages to provide a more comprehensive rehabilitation plan, as the current practice often involves coordinating different therapies using a "Rehab binder." Past experiences with the eRehabCog application indicated that patients might struggle to complete exercises independently, underscoring the need for a balanced combination of in-person and digital rehabilitation, along with personalized treatment plans. Additionally, the integration with the existing electronic health record (her) system, TakeCare, was deemed essential to avoid redundant administrative work.

6.2 Expectations and Attitudes

The digiphysical care flow prototype partially met the professionals’ expectations. While they recognized its potential benefits, there was concern that it might become an additional task for staff rather than streamlining the rehabilitation process. The importance of selecting appropriate patients who get access to the prototype was emphasized, as its effectiveness might vary depending on individual needs.

The professionals valued the potential for maintaining contact with patients even after the formal rehabilitation period had ended. They suggested using the chat feature to support keeping contacts for long-term behavior changes, recognizing that these adjustments often take time. This extended contact was seen as a valuable addition to the rehabilitation process.

6.3 Utility and Functionality

The digiphysical care flow prototype addressed several key needs and functionalities desired by the professionals. The inclusion of a chat function was highlighted as particularly useful, facilitating direct communication with patients without unnecessary delays. The ability for patients to complete self-assessments and fill out forms before appointments was also praised, with features like automatic scoring and summarization of these assessments enhancing efficiency.

Recorded exercises were identified as a significant advantage, especially for occupational therapists, as this feature is currently lacking in their practice. The professionals appreciated the customization options for exercises, allowing therapists to set specific times and repetitions tailored to each patient. Additional suggestions for extending the prototype included integrating weekly goals to break down treatment plans into manageable steps and incorporating visual timers within the app to guide exercise durations and rest periods.

6.4 Usability and Overall Design

While the digiphysical care flow prototype was generally considered user-friendly, some usability concerns were noted. Screen time was highlighted as a potential strain, particularly for the patient demographic. The interface, especially the inbox, was seen as complex. Simplifying screen layouts for certain patients and offering background color options, such as beige instead of white, were recommended to accommodate sensitivity issues.

Patients might require assistance to navigate the system, as some even find platforms like the Swedish website for health care support (called “1177”) challenging. The interface should be adaptable to different patient needs, with some requiring more straightforward designs. The inbox was described as somewhat complex, leading to a proposal to start with a calendar view to streamline navigation. Alternatively, a suggestion was to filter or customize the display to show only the day’s exercises.

Overall, the evaluation provided initial insights into the prototype's strengths and areas for improvement, emphasizing the need for flexibility, integration, and patient-specific adaptations.

7 Digiphysical Rehabilitation Patterns

This section outlines five digiphysical rehabilitation patterns developed in the project, aimed at integrating digital tools with physical rehabilitation processes. The patterns range from addressing the need for comprehensive process handling, such as the Digiphysical Rehabilitation Process, which integrates digital tools with physical treatments for a cohesive process, to more concrete suggestions like digitizing administrative tasks to reduce manual workload. A summary of the patterns is presented in Table 3.

7.1 Digiphysical Rehabilitation Process

A digiphysical rehabilitation process integrates digital and physical healthcare interventions into a unified process. This ensures that both clinical (patient contact, treatment) and administrative (scheduling, documentation) activities are managed and interconnected into a well-documented process. The process is designed to accommodate various treatment modalities – such as digital and on-site - making it adaptable to different healthcare settings and patient needs.

Problem: The primary challenge addressed by the Digiphysical Rehabilitation Process pattern is the fragmented nature of current rehabilitation systems, particularly for patients with cognitive impairments following COVID-19. Existing applications like eRehabCog and Cogmed function in isolation, necessitating manual data entry and offering little to no interoperability. This lack of integration creates inefficiencies, such as duplicated administrative work and difficulties in

tracking patient progress. To complicate things further, there are still activities that are paper-based, leading to interruptions in what could have been a supported digital process.

Table 3. Overview of the patterns

Pattern	Problem	Solution	Prototype Implementation
1. Digiphysical Rehabilitation Process	Fragmented systems support, isolated applications, paper-based activities	Integrates clinical and administrative tasks into one cohesive, adaptable process	The process-oriented tool supported the prototype with scheduling, assessments, exercises, and monitoring connected via an overarching process
2. Digital Administration in Rehabilitation	Manual and disconnected admin processes, duplication, and inefficiency	Digitally supported scheduling, documentation, and specialist allocation integrated with EHRs	Prototype supported both clinical and admin tasks. The tool supported integration with EHRs and applications such as eRehabCog and Cogmed
3. Digital Self-Assessments	Paper-based inefficiency, lack of personalization, static assessments	Online forms for pre/post visit assessments, automated data processing, visual feedback	Implemented forms in prototype; support for remote adjustments of plans according to assessments
4. Digiphysical Self-Rehabilitation	Lack of monitoring and motivation, rigid rehab plans	Remote-guided exercises with progress logging and feedback; videos and chat	The prototype included eye exercises with text/video guidance and feedback mechanisms. The tool supported process monitoring and playback.
5. Digital Interaction	Limited provider-patient communication; missed follow-ups	Chat functions for ongoing feedback, remote plan updates, data-linked communication	Patients completed digital forms pre-visit; chat was used for both admin and clinical interaction

Solution: Design of a Digiphysical Rehabilitation Process offers an integrated approach that combines digital and physical healthcare interventions into a cohesive process. This system unifies clinical activities – such as patient contact and treatment – with administrative tasks like scheduling and documentation. The process accommodates various treatment modalities, both digital and on-site, ensuring adaptability across healthcare settings and patients. A part of the pattern is to not only design each activity but to also design and implement support for the process that governs the activity coordination. Task automation, such as digital assessments and self-monitoring updates, reduces manual data entry, while real-time tracking and role-based task assignments improve coordination among healthcare providers.

Solution in the project: In the project, a broad approach was taken to digital support; thus, both clinical and non-clinical activities were analyzed. The digiphysical care flow prototype supports the entire rehabilitation process, offering features like appointment scheduling, assessment forms, self-rehabilitation exercises, and progress monitoring. What connects the activities is an overarching process. The process-based design was supported by the platform that utilizes the concept of the process for both the design and run-time execution of the prototype. An example of an executable process for planning a patient visit is shown in Figure 4.

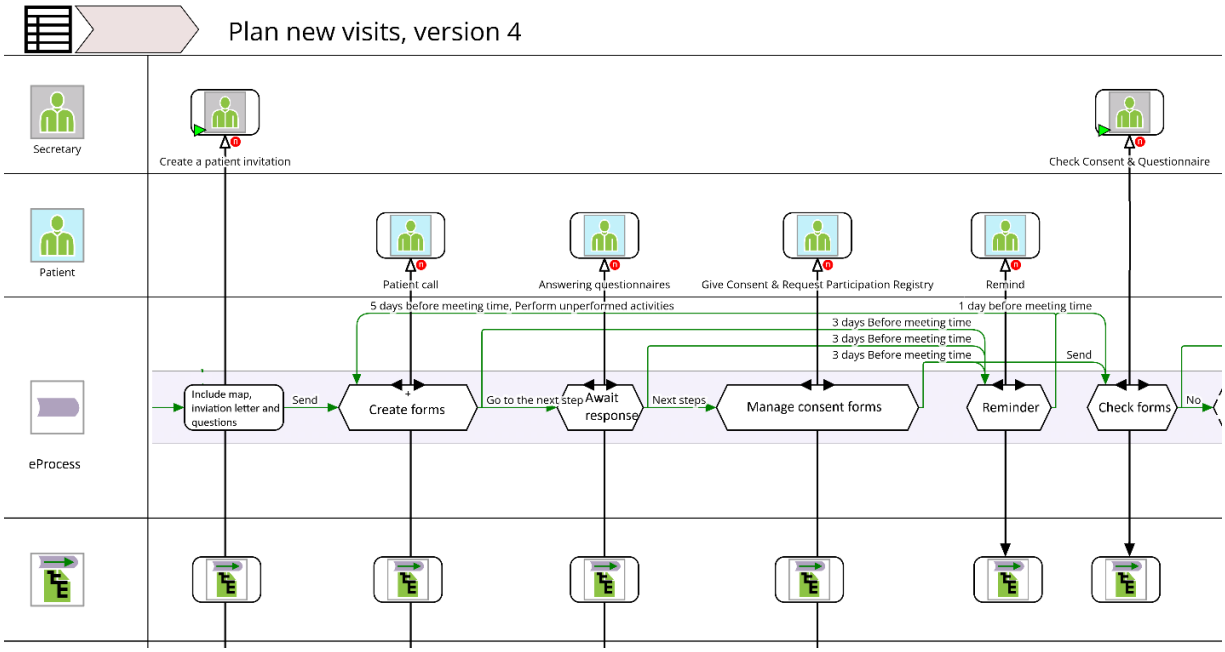

Figure 4. The executable process of planning a new patient visit

7.2 Digital Administration in Rehabilitation

Rehabilitation involves not only clinical treatments but also a significant amount of administrative work that handles the coordination of patient care. These non-clinical activities include scheduling visits, allocating patients to rehabilitation specialists, organizing group-based rehabilitation programs, and managing the documentation associated with the rehabilitation process. A digiphysical care approach can also encompass non-clinical tasks to achieve benefits.

Problem: Traditional methods for handling administrative tasks are often fragmented, relying heavily on manual processes. This may result in time-consuming scheduling, lack of integration between clinical and administrative workflows, and difficulties in tracking patient progress. The separation of administrative and clinical workflows may lead to redundant data collection across multiple systems, increasing the workload.

Solution: The integration of support for digital administration in rehabilitation addresses these inefficiencies by supporting administrative processes. Digital platforms can help in scheduling, ensuring that patients are assigned to the right specialists based on availability and specific needs. Further, the documentation of sessions is simplified, enabling progress tracking. Integrating digital administration tools with existing healthcare IT systems, such as EHRs, reduces the need for manual data entry and ensures communication between clinicians, administrative staff, and patients.

Solution in the project: In the context of the project, the prototype included the support for both clinical and non-clinical processes into a cohesive digiphysical care flow prototype. This solution addressed the fragmentation seen in traditional rehabilitation administration by enabling integration with EHR systems and the potential to integrate specialized rehabilitation applications like eRehabCog and Cogmed. The prototype facilitated scheduling, patient allocation, and documentation, allowing healthcare professionals to manage the entire rehabilitation process within the tool. The clinical and non-clinical activities were bound together by the process support offered by the used development platform. An example of an administrative form is provided in Figure 5, showing that the referral sent from an external healthcare organization indicates that the patient needs an interpreter and transport service.

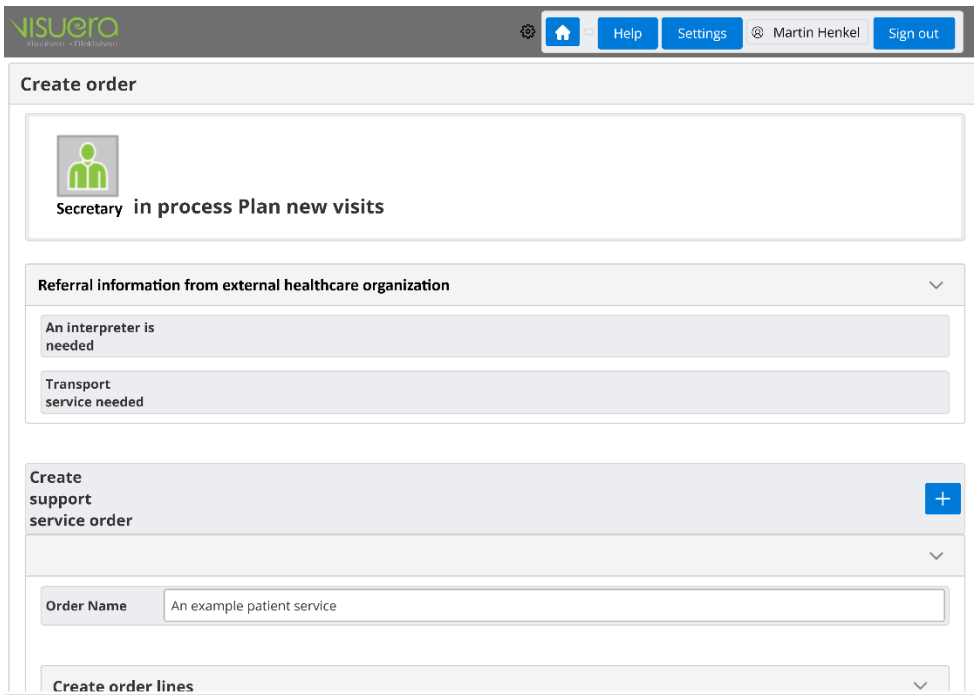

Figure 5. Excerpt of an administrative form for ordering special patient support

7.3 Digital Self-Assessments

In the context of rehabilitation, self-assessments are used to monitor cognitive function, fatigue levels, physical recovery, and overall well-being. These assessments help clinicians track changes over time and make data-informed adjustments to treatment plans. Additionally, automated analysis of assessment results facilitates longitudinal studies and improves the understanding of rehabilitation outcomes.

Problem: Traditional self-assessments in rehabilitation face several challenges as they are commonly paper-based and performed on-site. This makes the data collection inefficient since there are personnel that need to digitize the result and for example, calculate resulting scores. Furthermore, traditional self-rehabilitation programs are often static, failing to adapt to a patient's individual progress, fatigue levels, or specific rehabilitation needs. Making it possible to collect self-assessments in an easy and cost-effective way could pave the way for using more self-assessments during the rehabilitation process. This limitation reduces the effectiveness of rehabilitation interventions by not offering personalized adjustments to treatment plans.

Solution: Digital self-assessments address these challenges by supporting the data collection and analysis process. Patients can complete assessments using digital forms, which are available to give insights into their condition. This enables clinicians to adjust treatment plans, ensuring that rehabilitation interventions are responsive to patient needs. Additionally, digital applications facilitate the collection of large, structured datasets, supporting longitudinal studies and clinical evaluations. Features like visual progress charts and automated feedback mechanisms engage patients by allowing them to track their progress and stay motivated throughout their rehabilitation journey. Patients benefit from increased engagement and self-monitoring capabilities, fostering a sense of ownership over their rehabilitation journey.

Solution in the project: In the project, digital self-assessments were implemented using digital forms to assess cognitive function. Patients also completed pre-visit digital forms. The prototype, even though not fully functional in this respect, also included more advanced assessment functions like the Montreal Cognitive Assessment (MoCA). The design of the prototype allows clinicians to make adjustments to treatment plans. This, in combination with the ability to communicate with healthcare professionals via the chat function, makes it possible to adjust the rehabilitation exercises without on-site visits.

7.4 Digiphysical Self-Rehabilitation

Digiphysical self-rehabilitation refers to the integration of digital tools and physical rehabilitation exercises, enabling patients to independently engage in their rehabilitation process while maintaining support from healthcare professionals. This approach makes use of interactive rehabilitation programs to enhance patient autonomy.

Problem: Traditional self-rehabilitation models, which rely heavily on paper-based instructions and sporadic clinical follow-ups, present several challenges. One primary issue is the lack of continuous monitoring and feedback. Without regular oversight, both patients and healthcare providers struggle to ensure that exercises are being performed correctly and are yielding the desired outcomes. This can lead to ineffective rehabilitation and potential setbacks in recovery. Another significant challenge is patient motivation and adherence. Rehabilitation, especially over long periods, can become monotonous and discouraging without consistent encouragement and real-time progress tracking. Furthermore, traditional rehabilitation approaches are often rigid and fail to adapt to individual patient needs. This lack of personalization can hinder recovery, as patients may not receive the adjustments necessary for their specific conditions, fatigue levels, or progress.

Solution: The digiphysical self-rehabilitation model addresses these challenges by integrating digital applications that can be used both on-site when demonstrating exercises and at home when performing the exercises. Patients can also log their activities in a digital system, allowing clinicians to track progress remotely. This digital integration not only provides continuous feedback but also helps tailor rehabilitation plans to individual patient needs. Additionally, digital progress tracking plays a role in maintaining patient motivation, making the rehabilitation process more engaging and less burdensome.

Solution in the project: In the prototype developed for this project, the digiphysical self-rehabilitation approach was implemented for eye exercises. A set of sample exercises was put in the digiphysical care flow prototype, including directions in text and video. From the patient's perspective, it was possible to indicate strain and contact the optician for adjustment of the exercises. The use of a process-oriented tool allowed for the monitoring and playback of process instances.

7.5 Digital Interaction

Digital interaction in rehabilitation extends beyond basic administrative and data collection functions to ensure continuous communication, enabling communication about ongoing rehabilitation and also long-term patient follow-ups.

The primary *problem* in traditional rehabilitation communication is the limited interaction between patients and healthcare providers, which is often confined to scheduled visits or phone calls. This restriction creates several issues, such as inefficient and infrequent treatment adjustments. For instance, modifying the number of exercise repetitions or introducing new training elements typically has to wait until the next in-person appointment, delaying progress. Furthermore, traditional methods lack convenient communication channels for addressing simple but time-sensitive queries, like clarifying exercise techniques or managing minor discomforts. Another significant challenge is maintaining long-term follow-ups after formal rehabilitation ends. Without a digital platform, healthcare providers struggle to stay in touch with patients, making it difficult to assess recovery sustainability and provide ongoing support.

The *solution* to these challenges lies in implementing several digital interaction styles within rehabilitation programs. Firstly, communication can be context-specific. Digital platforms enable therapists to adjust treatment plans remotely based on patient feedback and progress tracking. Secondly, generic means of communication can be supported. One example is integrated chat functions, which allow patients to ask short, clarifying questions and receive instant feedback. This can be used for any type of question and may not relate to a specific context, such as a particular

rehabilitation exercise. Additionally, digital platforms may reduce the risk of losing contact after discharge.

Solution in the project: In the digiphysical care flow prototype, digital interaction was applied to support both clinical and administrative processes within rehabilitation. For instance, patients could fill in digital self-assessments before visits, and these assessments were then reviewed and discussed during in-person appointments. The integrated chat function enabled patients to ask questions and receive feedback without the need for additional physical visits.

8 Discussion

The development and evaluation of the digiphysical rehabilitation prototype led to several insights into the role of process design, digitization, documentation needs, and interactive elements in digiphysical care.

Process design is essential. One of the primary conclusions is the importance of process design in healthcare systems. Rather than focusing solely on separate digital activities, it is the integration of these activities into a consistent flow that enables bigger changes to the rehabilitation process. The digiphysical care flow prototype's ability to organize both clinical and non-clinical processes – from patient self-assessments to administrative scheduling – shows the capability to address the entire rehabilitation process. Non-clinical processes, such as appointment scheduling and follow-up communications, play an important role in ensuring smooth transitions between stages of rehabilitation. The coverage of these processes by the prototype was positively noted by rehabilitation professionals, indicating the usefulness of a system that reduces manual data entry and potential errors.

Digitization is a base enabler. Plain digitization serves as a foundational enabler in the rehabilitation process. The prototype's use of a tool, Visuera Information Manager, exemplifies how making the development of small digital activities, such as digital forms and self-assessment applications, efficient and inexpensive can lay the groundwork for more comprehensive digital healthcare support. The model-driven, no-code approach of Visuera Information Manager facilitates rapid development. This ensures that even minor activities, previously deemed to be too trivial for digitization, are now integrated into the digital flow, enhancing the overall digitalization of the care flow. The ability to quickly develop and modify digital components also supports scalability, enabling the expansion of the prototype to accommodate additional rehabilitation activities.

Leverage combined activities. The digiphysical approach of the prototype illustrates the benefits of integrating digital flows with on-site visits. By combining physical and digital elements, the digiphysical care flow prototype enhances the rehabilitation process's flexibility and effectiveness. For instance, during visits, the prototype facilitates personalized exercise planning, which patients can continue at home with digital support. Rehabilitation professionals appreciated the prototype's ability to support combined activities.

Support forms of interaction. The prototype supports various types of interaction, including real-time, chat, and asynchronous communication. This flexibility allows for different types of patient care delivery depending on the rehabilitation activity. For instance, real-time interactions during visits can be followed by asynchronous digital updates. The chat function helps maintain communication between patients and healthcare providers, even after treatment, allowing for follow-ups and adjustments based on patient feedback.

In conclusion, the digiphysical rehabilitation prototype demonstrates the importance of process design, the enabling role of digitization, the benefits of combined digital and physical activities, and the necessity of flexible interaction types. While these elements collectively contribute to a more efficient, patient-centered rehabilitation process, the evaluation also highlighted the complexity inherent in implementing the prototype in a care organization. Rehabilitation professionals noted potential challenges, such as the increased workload from additional data entry requirements and the need for careful modeling to avoid overburdening staff.

9 Conclusion

This article explores the application of the digiphysical care principle in post-COVID rehabilitation through the design, development, and evaluation of a digital rehabilitation prototype. The digiphysical care principle refers to the overarching approach of integrating digital tools with physical rehabilitation to create a seamless and efficient care model. Applying this principle in practice requires structured methodologies and tool support. To address this, the study introduces five solution patterns – digiphysical rehabilitation processes, digital administration, digital self-assessments, digiphysical self-rehabilitation, and digital interaction – which are presented in Section 6. These patterns serve as practical implementations of the principle, offering structured ways to integrate digital tools with physical rehabilitation practices.

The prototype serves as a practical implementation of these patterns, demonstrating how digital and physical components can complement and enhance each other to create a cohesive rehabilitation process. It provides functionalities that address key challenges in rehabilitation, such as streamlining administrative tasks, enabling self-rehabilitation, facilitating digital assessments, and enhancing clinician-patient interactions. By structuring rehabilitation through process-oriented digital support, the prototype illustrates how digiphysical care can be systematically applied to improve clinical processes, administrative processes, and patient outcomes.

An evaluation with rehabilitation professionals revealed a generally positive reception regarding the prototype's utility, functionality, and usability. Professionals valued the structured approach to integrating digital and physical rehabilitation activities, the prototypes' ability to personalize patient engagement, and features such as automated self-assessments and direct communication.

A key insight from the prototype development was that process design, rather than isolated digital applications, is pivotal for effective implementation. The prototype's ability to support combined digital and physical activities underscores the benefits of digiphysical care. Moreover, a platform-based digitization approach provides a scalable foundation, enabling the rapid development of new rehabilitation activities and the integration of even minor administrative tasks.

Despite its promise, the full impact of digital and digiphysical healthcare remains only partially understood [38]. Future work will include ongoing evaluations, involving patients directly to further assess the prototype's utility, functionality, and usability from the patient's perspective. Special focus will be given to evaluating the user interface for patients with vision impairments, ensuring that it is accessible and user-friendly. The insights gained from these evaluations will guide continuous improvements in the prototype's design and implementation.

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