Applying a digiphysical approach for post-covid rehabilitation

Martin Henkel[1]*, Erik Perjons[1], Kristian Borg[2], Uno Fors[1], Jan Johansson[3], Marika C. Möller[2,4], Christer Wåhlander[5], and Kalle Wåhlander[5]

[1] *Department of Computer and Systems Sciences, Stockholm University, SE-164 25 Stockholm, Sweden*

[2] *Karolinska Institutet, Department of Clinical Sciences, Danderyd Hospital, Division of Rehabilitation Medicine, SE-182 88 Stockholm, Sweden*

[3] *Department of Clinical Neuroscience, Division of Eye and Vision, Karolinska Institutet, SE-171 64 Stockholm, Sweden*

[4] *Danderyd University Hospital, Department of Rehabilitation Medicine, SE-182 88 Stockholm, Sweden*

[5] *Visuera Integration AB, SE-113 59 Stockholm, Sweden*

Abstract

Patients with long-term cognitive impairments following COVID-19 face significant challenges in their rehabilitation, which involves essential therapeutic procedures, administrative tasks, diagnostic tests, and self-assessments. "Digiphysical" methods, combining digital and physical healthcare interventions, offer promising solutions to enhance these rehabilitation processes. In this paper, we present a newly developed digital rehabilitation prototype based on the digiphysical approach. The prototype is designed to integrate digital and physical interventions, streamline clinical and administrative tasks, support the entire rehabilitation process, and facilitate self-directed rehabilitation. It addresses the rehabilitation needs from both the patients' and the rehabilitation personnel's perspectives. In this paper, we present the results of an initial evaluation of the prototype conducted with key rehabilitation professionals.

Keywords

Healthcare process, Rehabilitation process, Digiphysical systems, Digital healthcare

1. Introduction

A growing patient demographic is exhibiting persistent cognitive impairments following COVID-19 infection [1]. When symptoms last more than 12 weeks post-infection, the condition is often referred to as Post-COVID-19 Condition (PCC) [2]. Patients within this group frequently experience cognitive issues, fatigue, and, in some cases, visual function disturbances [3]. Intense international research is underway to establish causal links between COVID-19 and subsequent cognitive impairment in these patients (see, for example, Kelly et al., [4]).

Existing digital tools are available for the rehabilitation of patients with cognitive impairments from acquired brain injuries. However, these tools are not specifically designed for cognitive impairments following COVID-19 infections. Moreover, they only support a subset of the rehabilitation process. For instance, "eRehabCog" is a digital tool for patients with brain injuries, offering a remote education program lasting up to 12 weeks [5]. This program increases the patient's understanding of the neurological basis of their brain injuries and the symptoms they cause while also providing support for behavioral changes to improve daily life. The tool

BIR-WS 2024: BIR 2024 Workshops and Doctoral Consortium, 23rd International Conference on Perspectives in Business Informatics Research (BIR 2024), September 11-13, 2024, Prague, Czech Rep.

* Corresponding author.

martinh@dsv.su.se (M. Henkel); perjons@dsv.su.se (E. Perjons); kristian.borg@ki.se (K. Borg); uno@dsv.su.se (U. Fors); jan.johansson.1@ki.se (J. Johansson); marika.moller@regionstockholm.se (M. C. Möller); christer.wahlander@visuera.com (C. Wåhlander); kalle.wahlander@visuera.com (K. Wåhlander)

0000-0003-3290-2597 (M. Henkel); 0000-0001-9044-5836 (E. Perjons); 0000-0001-8748-1772 (K. Borg); 0000-0002-1093-4179 (J. Johansson); 0000-0001-8700-5186 (M. C. Möller)

aims to enhance patients' awareness of their cognitive impairments and managing daily activities.

In 2023, eRehabCog was partially adapted for patients with cognitive impairments following a COVID-19 infection by the Department of Rehabilitation Medicine in Stockholm (RUS) at Danderyd University Hospital, Sweden. Another tool used at RUS is "Cogmed" [6], aimed at improving working memory and attention in patients with eg. ADHD and acquired brain injuries. Although not specifically adapted for post-COVID-19 cognitive impairments, modules from this tool could potentially be used to train cognitive functions in these patients.

None of these tools, however, support the entire rehabilitation process comprehensively, which is the goal of the new rehabilitation tool being reported on in this paper. This tool aims to address the cognitive training needs of PCC patients by, for example, linking to modules in both eRehabCog and Cogmed, but also provide a set of other functions.

The tool is built with a digiphysical method approach that aims at aligning the physical and digital aspects of the rehabilitation. According to the Region Stockholm, digiphysical care is a care where physical and digital channels complement each other [7].

The tool supports the entire rehabilitation process from both the patients' and the rehabilitation personnel's perspectives. For patients, it offers features such as viewing appointment notices, preparing for physical visits, completing assessment forms, performing self-rehabilitation exercises, and managing follow-ups. Additionally, the tool assists clinical and administrative personnel at rehabilitation clinics by streamlining activities such as managing referrals, organizing team meetings, sending appointment notices, presenting digital assessment forms, and monitoring patients' self-rehabilitation progress.

Furthermore, a significant portion of the PCC patient group also shows vision-related problems after COVID-19 [8]. These problems are similar to those found in patients who have suffered brain injuries [9]. Therefore, functions for management of vision therapy have been developed in the tool since this is not part of the previous mentioned eRehabCog and Cogmed tools.

In a previous project at RUS, several key needs were identified for this patient group, including the ability to monitor patients remotely, provide a chat function for communication between patients and rehabilitation personnel, and adjust the frequency and intensity of cognitive training remotely [10]. These needs formed the foundation for developing the new rehabilitation tool.

As the PCC patient group is expected to grow, the workload on rehabilitation healthcare will simultaneously increase. A remote rehabilitation tool could alleviate the healthcare burden and free up resources.

2. Research problem, question and methodology

A prototype of the new tool has been developed in a research project conducted between 2021 and 2024 [11]. The project addresses the challenge of designing a digital rehabilitation tool that enables PCC patients to engage in rehabilitation with professional support while also assisting rehabilitation professionals in effectively managing the rehabilitation process.

This project aims to develop and evaluate a prototype of a digital rehabilitation tool built with a digiphysical approach, and investigating how such a tool should be designed to effectively support the rehabilitation of patients with long-term cognitive impairments following a COVID-19 infection. While the evaluation with professionals has been conducted, the current focus of this paper is on their perspectives regarding the tool's utility, functionality, and usability.

The research question to be answered in the paper is: How do rehabilitation professionals view the utility, functionality, and usability of a digital tool designed to support the rehabilitation of patients with long-term cognitive problems following a COVID-19 infection?

The prototype was developed by system developers at Visuera Integration AB, Sweden (see https://visuera.com/), in collaboration with researchers from the Department of Computer and Systems Sciences (DSV) at Stockholm University, and rehabilitation professionals from RUS (Danderyd University Hospital) and Karolinska Institutet. The team included a specialist in rehabilitation medicine, a neuropsychologist, and a neuro-optometrist, who helped tailor the prototype to the specific needs of the rehabilitation department. This collaboration primarily occurred through meetings conducted via the Zoom video conference platform.

The project's research strategy is action research, characterized by a collaborative and iterative approach in which system developers, researchers, and rehabilitation professionals work together to develop and refine the digital rehabilitation tool. The emphasis on practical outcomes, such as improving rehabilitation practices, along with continuous reflection on the tool's design and usability, aligns with the core principles of action research.

The evaluation with rehabilitation professionals, presented in this paper, was conducted through a group interview with four rehabilitation professionals at RUS, including a physician, a psychologist, and two occupational therapists (more details on the group interview are presented in section 4).

The prototype of the digital rehabilitation tool aims to support patients in conducting cognitive self-rehabilitation. It also supports personnel at rehabilitation clinics in efficiently conducting clinical and administrative activities related to a patient's rehabilitation, including supporting the patient's self-rehabilitation. As healthcare moves towards increased digitalization to manage economic challenges, there is currently a lack of a digital rehabilitation tools tailored for PCC patients.

3. The development platform and prototype tool

In the project, a new model-based development platform, Visuera Information Manager, has been used, containing tools for model and execute processes, and provide support for integration with other systems. The platform has its base in integration solutions such as EAI engines (message brokers) and business process management systems (process brokers), earlier developed by the team members behind Visuera Information Manager, see www.visuera.com, see also, for example, [12,13,14]. Thereby, the platform will be able to integrate different types of systems.

The platform supports rapid model-based design, implementation, and execution of healthcare processes, and is designed so that care personnel can be involved in all phases. The platform is also a no-code platform that runs on the web. Thus, developing new screens and changing the process requires no coding, making development of new activities less resource intensive compared to traditional development platforms.

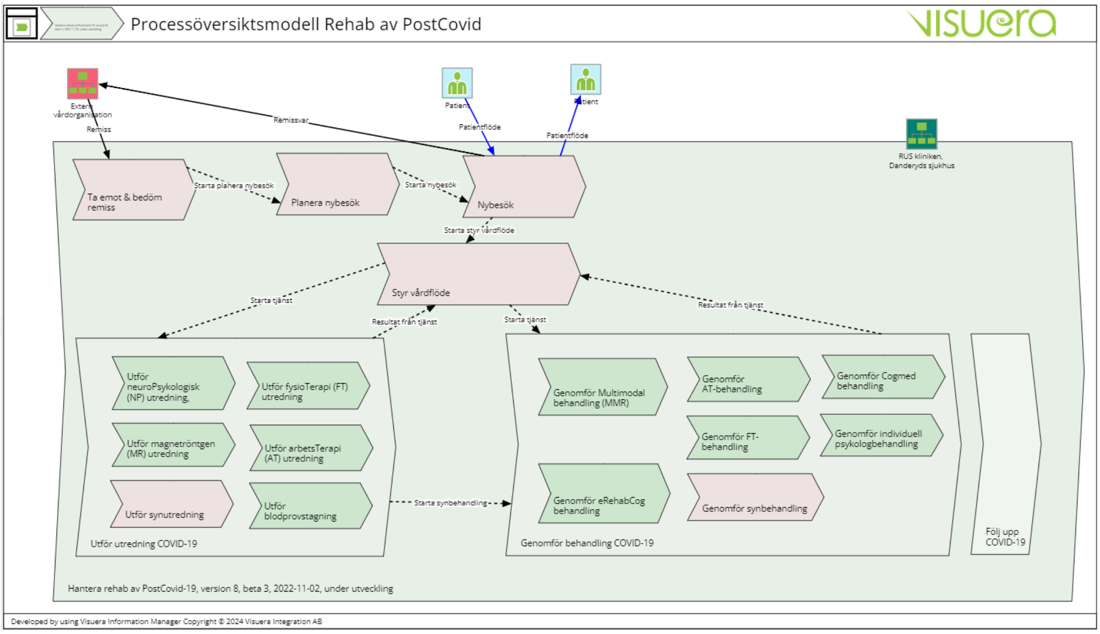

Figure 1: Process overview model

In the platform, an overview model (figure 1) is used to structure the application during the design phase. Since it is a process-based tool, the overview shows the components of the application in the form of processes and sub-processes. That is, the overview model shows the processes and sub-process supported by the tool, and how these processes and sub-processes are related to each other. By opening up one of the sub-processes in the overview, it is possible to design that process in detail. This more detailed process design (figure 2) will be executed during tool run-time.

The process-based model (figure 2) enables the integration of roles, digital interaction with these roles via user interfaces, physical interactions and e-process activities. In center is the e-process that consists of automated activities that, based on input from the roles via user interfaces, drive the process forward. The activities in the e-process are also linked to information sources, which may include external system (to be integrated with the platform), documents, and data connected to the process instance (case data). Thus, the process-based model described the coordination of physical, manual, automated, and information flows.

The features that make the tool particularly well-suited for integrating digital and physical healthcare is the use of the process-based model since it depicts both automated and manual activities, as well as the users' interaction with the tool via user interfaces. Thereby, the model can, for example, represent physical, digital, and digiphysical visits between a patient and a physician.

The overall process-based model utilizes a structure similar to that of the modeling language BPMN (Business Process Model and Notation). The differences are that the model allows for both the process description (horizontally) and the interaction of roles and information sources (vertically), see figure 2. During execution of a process model, the model dictates which user interfaces to be made available to users depending on their specific roles, and which data to receive and send to the information sources.

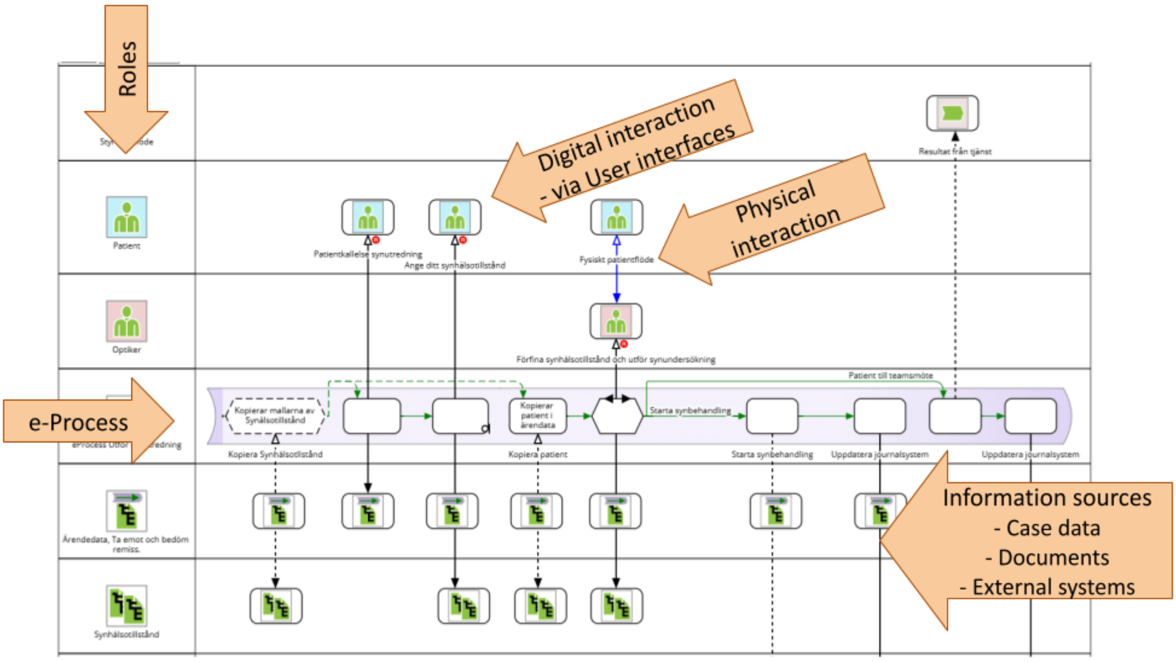

Figure 2: A fragment of the detailed process model created for the rehab process

For each user-interface activity depicted in the model, there is an option to design a corresponding user interface. An example of such a user interface is shown in Figure 3. As illustrated, the interface is designed using traditional forms. In the prototype, there are several designed processes and sub-processes, and, for each process, many user interfaces are often designed.

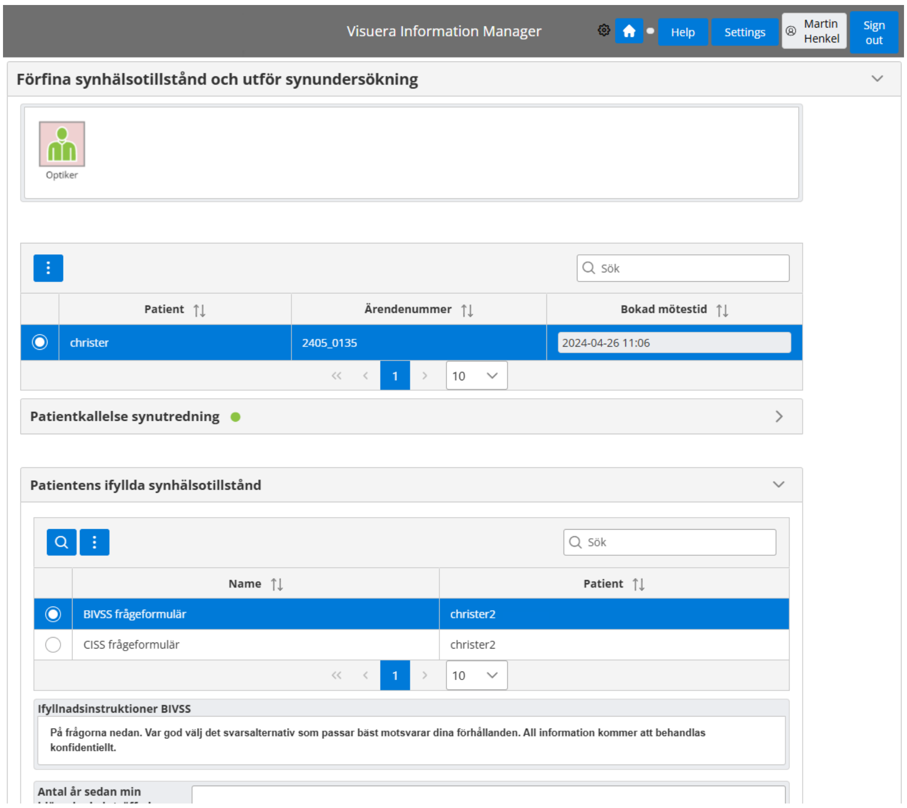

Figure 3: An example of a user interface from the tool

To provide an overview of the prototype's capabilities, table 1 details a process that the prototype is designed to support: the Vision treatment process. This process is intended to assist in the rehabilitation of PCC patients with vision-related problems and has been adapted for integration with the prototype. It is important to note that the process described in table 1 does not fully reflect the current practice, as the prototype is not yet in use.

In this process, a patient undergoes an examination by an optometrist and, if appropriate, is prescribed therapy targeting specific visual functions. For example, the therapy may be intended to strengthen the alignment, or teaming, of the eyes to improve the focusing ability (referred to as the Brock String Exercise).

As shown in Table 1, the prototype is designed to support a range of activities, including physical, digital, and digiphysical activities, as well as both clinical and non-clinical/administrative activities. For instance, a clinical activity might involve conducting a vision examination during an optometrist visit, while an administrative task could be creating and sending an appointment notice for this examination. Additionally, some activities, like the chat function, are flexible and can be performed at any time.

Table 1

Vision treatment process, adapted to be supported by the prototype tool.

Treatment personnel activities	Patient activities
Create and send an appointment notice to a patient for a vision examination visit (digital, using the tool)	Read the appointment notice for the vision examination visit (digital, using the tool)
	Make a visual health condition self-assessment as a preparation for the visit (digital, using the tool)
*Digiphysica*l visit with an optometrist: Refine the visual health condition self-assessment, and perform a vision examination to be recorded in the tool (physical and digital)	
Create vision treatment exercises for the patient's home-based rehabilitation - a first draft (digital, using the tool)	
Create and send an appointment notice to the patient for a vision treatment visit (digital, using the tool)	Read the appointment notice for the vision treatment visit (digital, using the tool)
Digiphysical visit: Finalize the vision treatment exercises for the patient's home-based rehabilitation in the tool together with the patient (physical and digital)	
	Conduct vision treatment exercises, and based on the training, provide self-assessments (digiphysical, both carry out physical exercises, and record the assessment of the training in the tool)
At any time: Eventually remind patient about conducting vision treatment exercises (digital, using the tool)	Read reminder (digital, using the tool)
Check vision treatment result and patient's self-assessment - and eventually modify the vision treatment exercises (digital, using the tool)	*If modified:* Read info about the modified vision treatment exercises (digital, using the tool)
Create and send an appointment notice for a vision treatment follow-up visit (digital, using the tool)	Read the appointment notice for the vision treatment follow-up visit (digital, using the tool)
Physical or digiphysical visit: Vision examination follow-up (physical and maybe digital if using the tool)	
Create and send analysis of vision treatment after follow up (digital, using the tool)	Read analysis (digital, using the tool)
Digital at any time: Chat	

4. The tools' fit for digiphysical healthcare

Regarding the effect of cognitive rehabilitation, it has been shown that digital rehabilitation in itself is not recommended unless the patient receives metacognitive support from a treating therapist [15]. Therefore, combining digital and physical interaction between a therapist and a patient may be useful approach. The term "digiphysical approaches" in healthcare refers to an integrated method that combines digital and physical care interventions to offer patients a more flexible, accessible, and efficient healthcare experience. Although the term "digiphysical approaches" is not universally established, it can be understood within the context of how healthcare integrates digital and physical interventions to create effective and patient-centered care processes. The concept began to be used in Sweden relatively recently when a combination of digital and physical meetings and treatments became more common. The Region Stockholm, responsible for healthcare in the Stockholm region, describes digiphysical care as care where "physical and digital channels complement each other" [7]. Furthermore, it is described that this flexibility in providing care should increase accessibility and promote patient involvement.

To illustrate how the prototype supports digiphysical care and how the rehabilitation professionals perceive the prototype, we have divided digiphysical care into five areas: Care processes, Digital solutions, Physical solutions, Combined approaches, and Accessibility. We examine how the prototype and its platform support each of these areas in the following sections. For each area, the following is summarized: First, the *problems* that exist today in post-COVID rehabilitation. Second, the developed prototype's *solutions* to the problems, and, third, the *evaluation* of the prototype approach carried out by the rehabilitation professionals.

As mentioned earlier, the initial evaluation was carried out in form of a group interview with four rehabilitation professionals at RUS (a physician, a psychologist, and two occupational therapists). First, the tool and the activities in the Vision treatment process (see table 1) were briefly presented to the personnel (during 10 minutes). Then, for each step in this process, screenshots of the tool were presented to demonstrate the tool (during 15 minutes). Finally, a discussion among the professionals was carried out (during 35 minutes). The discussion was based on a set of questions regarding the expectations, functions, usability, and utility of the tool.

The concept of digiphysical care was not introduced to the rehabilitation professionals during the evaluation. Instead, the concept has been used during the analysis of the evaluation discussion. The result of the analysis is presented in the following sub-sections.

4.1. Care processes

Healthcare processes are generally divided into two categories: clinical and non-clinical. Clinical processes involve direct interactions with patients, focusing on their health, and also include activities such as recording symptoms, vital signs, and planned and carried out treatments. Non-clinical processes encompass administrative tasks, such as scheduling appointments and communicating appointment details to patients. Both types of activities/processes can be supported digitally.

The current **problem** with digital systems in healthcare is that they often fall into one of two categories: broad solutions that provide general support across many areas but lack depth, or specialized systems that offer deep functionality for specific issues. An example of a broad solution is Electronic Health Record (EHR) systems. These are generic, standardized platforms that cover a wide range of processes, both clinical and administrative/non-clinical, with basic capabilities for data recording. On the other hand, systems that address narrower aspects of healthcare, such as rehabilitation tools like eRehabCog and Cogmed mentioned earlier, focus on specific treatments or parts of the treatment process but do not cover the entire process.

Therefore, while these specialized systems excel in their respective areas, they do not provide comprehensive coverage of the entire healthcare process. Currently, broad systems like EHRs and narrow, specialized tools like eRehabCog are often used together without integration. This lack of integration forces users to manually input data into multiple systems, resulting in increased workload.

The **solution** tested in the prototype addresses both clinical and administrative/non-clinical processes/activities, and their result. This leads to a fully integrated solution, sparing users from switching between systems, saving user time and also increasing quality in the process.

This solution does not aim to incorporate all functionalities within a single system. Instead, the platform's integration capabilities make it possible to integrate different applications/systems, for example, eRehabCog and Cogmed. The platform's integration capabilities make it also possible to automatically register necessary data from the tool into an EHR system.

The platform's use of a model-driven and no-code development approach also means that new components of the solution can be developed relatively quickly - this implies that areas previously considered too trivial for digitalization can now receive digital support. This guarantees digital support encompassing more activities, including those currently conducted physically only using paper forms.

During the **evaluation**, several pros and cons, and suggestions for changes in how the prototype handles the entire rehabilitation processes, were discussed.

The prototype's main *advantages*, according to the respondents, were its ability to offer a clear, adaptable treatment process and a structured patient follow-up. The prototype's coverage from initial patient contact to final treatments, was seen positively. Digitalizing several smaller parts of the process to create a cohesive whole was also viewed favorably.

One of the prototype's main *drawbacks* is the risk that the approach might not suit all types of treatments. The tool is not always useful for treatments that require only physical presence or group interactions, which could limit its applicability. Moreover, the risk that implementing the tool could lead to increased workload for healthcare personnel. For example, to record additional data (not digital recorded before) in a tool is becoming yet another task to manage for the personnel. Therefore, careful modeling and selective use of manual recording are required to avoid overburdening the staff.

Several suggestions were made to *improve* the prototype. One interesting aspect is the desire to support additional processes and activities. It was particularly noted that maintaining ongoing patient contact over time was of interest, even after treatment has been concluded, for long term follow-up. Additionally, support for even more types of treatments was desired - supporting many treatment processes means they can be coordinated effectively in the tool, as a patient may have several different treatments simultaneously. To integrate the tool with the EHR system used by the clinic was pointed out as crucial to reducing administrative work and ensuring a smooth documentation process, that is, not be forced to record the same data in multiple systems.

4.2. Digital solutions

Digital technology, such as video consultations, e-prescriptions, and self-care apps, is already available for patient use today. A driving force behind some of the technologies is the opportunity for patients to receive information and advice remotely, which can be particularly useful for those with limited mobility or who live in remote areas.

However, the current situation regarding COVID-19 treatment is **problematic**: initial contact with primary care can occur digitally, for example, using a video service to contact primary care. Referrals to specialists are now also digital in Sweden. However, much is still non-digital once a contact with specialist care is established. There is simply a large amount of activities still handled with paper. A paper form may seem trivial, but it creates extra work when, for example, filled-in values need to be summed up, analyzed or transferred into the EHR system.

The patient record (e.g., an EHR systems) is digital, but this is used by medical personnel and is, in most cases, not for the patient. Moreover, digital tools that exist (like eRehabCog and Cogmed) are appreciated but support only individual activities in the care process (see discussion under “Care Processes”).

As already mentioned, the **solution** being built in the prototype has the advantage that new parts can be quickly developed. For instance, several digital forms were implemented in the prototype based on paper predecessors. Some parts were developed only for the patient, and others, such as assessing the patient’s progress, were developed for healthcare personnel. A central part of the solution is the ability to scale up to cover more activities quickly. Crucial to this scalability is the use of a platform that avoids "reinventing the wheel" — by leveraging fundamental features like user authentication and integrating with existing, well-established solutions.

During the **evaluation**, several *positive aspects* of the tool were pointed out. A fundamental comment was that the patient has the opportunity to perform exercises from home, which was appreciated as it eliminates the need for travel, which takes time and can be strenuous for the intended patient group. Furthermore, the digitalization of even simple forms was considered positive. For example, the opportunity for patients to make self-assessments by filling out forms before a visit is valuable. Also, using "smart forms" that automatically correct and sum these self-assessments was deemed to improve efficiency. Part of the tool includes the ability to customize the patient's exercises - this function was appreciated as it provides a better opportunity for an individual treatment plan. An interesting aspect was that a relatively simple function in the tool - the ability to chat with a patient - was appreciated. This provided an opportunity for feedback from the treating personnel to the patient and vice versa.

During the evaluation, *no direct disadvantages* with the digitally performed activities were discussed. As previously mentioned, more treatment forms in the tool were desired, i.e., that more activities could be supported digitally. This requires more modeling work in the tool for the modeler. Issues regarding accessibility of the tool for the PCC patient group, is discussed in section 4.5.

4.3. Physical solutions

Today, physical visits are generally considered the foundation of care. Many of these meetings are deemed necessary, for example, to take samples and assess symptoms. However, digital visits are increasingly becoming an option, for example, the use of video meetings.

A **problem** with today's COVID rehabilitation is that it mostly occurs through only physical meetings, without digital support, despite the fact that many patients complain that their fatigue contributes to them not being able to travel to the rehabilitation sessions to the extent needed. The lack of digital support is not due to an active decision but rather because there has been no opportunity to develop such options. Additionally, there has been no established methodology or systematic approach to determine which aspects of rehabilitation should incorporate digital support or be entirely replaced by digital services. Furthermore, certain patient groups are either unwilling or unable to participate in digital care.

An important task when developing the **solution** in the project was to identify which aspects of rehabilitation could be handled entirely or partially through digital means, while also making physical meetings more effective. The emphasis in the project has been on supporting the physical meetings rather than replacing them. As a result, the number of physical meetings will not decrease but will be supplemented with digital services.

During the **evaluation**, the focus was on the digital tool, but several of the comments was rather about the interaction between physical and digital activities. These are mainly treated in the next section. One thing that was emphasized, however, is the continuing need for physical visits, as these are considered very important for the rehabilitation treatment. Some physical visits, such as those with the physiotherapist or occupational therapist, are by nature difficult to replace. A *positive* aspect of the tool, however, is that these visits can be expanded with digital material, for example, patients can take home a recording of performed therapy exercises and continue to exercise in their own home environment, which in itself increases successful implementation. This digital material connects well to the physical meeting if it is patient-adapted, and not just generic instructions given on paper.

4.4. Combined efforts

Combined efforts refer to the integration of physical meetings and activities with digital meetings and tools. The goal is not to separate activities into digital or physical categories but to create processes where both digital and physical elements work together seamlessly. While care processes aim to integrate various activities into a cohesive whole, the focus of combined efforts is to develop specific activities that blend both digital and physical components.

The **problem** with current COVID treatment is that activities are usually either digital or, more commonly, physical. As a result, some activities that could benefit from digital tools remain entirely non-digital, leading to missed opportunities for greater efficiency. One exception is the eRehabCog system, which is used after physical meetings.

The **solution** in the project has been to analyze the entire rehabilitation process and, where possible, introduce digital performed activities. For example, patients can fill in digital self-assessments before a visit. During the visit, both the patient and treating personnel can go through and discuss the self-assessments. Moreover, treatment exercises can be reviewed during the visit as well. The patient can then take home a tailored digital description of the exercises to be performed for self-rehabilitation. If questions arise, the patient can use the prototype's chat function to ask questions to the rehabilitation personnel. Thus, physical and digital solutions can go hand in hand.

The **evaluation** showed that combined efforts were appreciated. Personnel experiences, among others from eRehabCog, show that patients often find it difficult to complete digital exercises independently, indicating a need to combine digital rehabilitation with personal visits and tailored treatment. Moreover, the prototype provided this opportunity for tailored exercises, which was considered positive. Another positive aspect was that patients could document how tired they became from doing the exercises using the prototype's functions. This allows treating personnel to adjust the exercises without a further physical meeting.

During the evaluation it was also pointed out that it would be good to maintain contact with the patient even after the treatment is completed to be able to conduct long-term follow-ups. An opportunity is to use the prototype's chat function for this. Support for this long-term follow-up would be good since a part of the treatment and exercise is to achieve behavioral changes - and these takes time.

4.5. Accessibility

Accessibility in healthcare involves making care available to a wide range of patients. Digiphysical approaches fundamentally improve access by reducing waiting times and simplifying the process of booking and attending appointments. However, for these digital solutions to be effective, they must be designed with the patients' needs in mind.

Patients undergoing post-COVID rehabilitation often experience fatigue, making it exhausting to travel to healthcare facilities. Additionally, some patients suffer from vision problems, making it difficult to focus or read for extended periods. This challenge is compounded in digital systems, where reading and using screens provide difficulties for the patients. This presents both an opportunity and a **problem** for digiphysical approaches: while digital services reduce the need for travel, they also require user interfaces specifically designed to accommodate this patient group.

The **solution** in the prototype has been to design the user interface in a standardized way. All activities and screen designs are structured so that navigation is uniform. Additionally, the platform allows for the rapid digitalization of several activities. The goal is to support both direct digital use by patients and to facilitate joint use of the prototype by patients and healthcare providers, especially for those who cannot or prefer not to use digital tools independently.

The **evaluation** stated some disadvantages with the prototype's design. When there is a lot of information on the screen simultaneously, such as in the "inbox". It was deemed that this can overwhelm some patients. A possible solution is to adapt or filter the content by only, for example, showing today's exercises. This can reduce cognitive load and make it easier for patients to focus on what is most relevant. A simple thing like the prototype having a white background can also cause problems for some patients since they are sensitive to light. An interesting aspect that came up during the project is that for some patient groups, it might be easier to read text on a mobile phone, as its screen is narrow and the eyes thus do not need to move so much. A similar narrow screen could be designed into the tool even when viewing it using a wide computer screen.

The evaluation also gave several *suggestions for improvements*. One suggestion was to show only a calendar with scheduled activities in the inbox instead of all activities. The calendar could then be set to show only one day or the coming week. Further, the need for help using the system was pointed out. An example of a patient group needing support involves those using the Swedish healthcare portal, "1177" which can be challenging to navigate for some. These patients may require additional assistance to ensure access to the necessary information.

5. Conclusion and discussion

The research question addressed in this paper is: *How do rehabilitation professionals view the utility, functionality, and usability of a digital tool designed to support the rehabilitation of patients with long-term cognitive problems following a COVID-19 infection?* To answer this, an evaluation was conducted with rehabilitation professionals.

Overall, the professionals viewed the digital rehabilitation tool prototype positively. They appreciated its ability to integrate clinical and administrative processes, which could lead to a more structured treatment approach. They also valued the tool's adaptability in creating customized treatment plans and its convenience for patients, such as allowing exercises to be performed at home with the possibility of remote refinement by rehabilitation personnel. The combination of digital and physical activities, like using digital forms for self-assessment before physical meetings, was particularly appreciated. The chat function was also highlighted as a valuable feature, enabling direct communication between patients and healthcare providers for timely feedback and support. Additionally, the tool's potential to coordinate multiple ongoing treatments for a patient, if several processes are designed into it, was noted as a significant advantage.

However, the professionals also identified potential drawbacks, including the risk of increased workload for staff if additional data recording is required, and the challenges in applying the tool to treatment processes that are primarily physical or involve group interactions.

Several suggestions were made to improve the tool's user interface for the PCC patient group: implementing filters to display only relevant content to reduce cognitive load; offering background color options for patients sensitive to light; developing a narrower screen layout similar to a mobile phone display to make it easier for patients with vision problems to focus on content; and providing a simplified calendar that shows only scheduled activities to make navigation more straightforward.

This paper also serves as an initial exploration of how a prototype tool aligns with the goals of digiphysical healthcare. It suggests not only examining existing physical or digital activities but also exploring potential future activities enabled by digital support. Some activities might not exist today simply because they are too costly to implement without digital solutions. For example, maintaining contact with patients even after treatment is a promising activity that digitalization could facilitate. Scaling the solution involves making it easy and cost-effective to add new combined digiphysical activities. Even trivial forms can be digitalized and later used in downstream processes for further digitalization. Achieving this scalability requires a platform that supports rapid development.

Despite its potential, the full impact of digital and digiphysical healthcare is still not fully understood [16]. Future work on the platform and tool will include ongoing evaluations, this time involving patients directly. We will continue to assess the utility, functionality, and usability of the tool, with particular attention to how well the user interface works for patients with vision impairments. The insights gained from these evaluations will guide the continuous improvement of the tool's design.

The prototype tool described in this paper was specifically designed for COVID-19 rehabilitation, but it has revealed broader patterns in healthcare processes. There is a standardized way in which patients move through the system, including notifications for visits, decisions on further treatments, and communication with patients about these treatments. In the project, these steps were managed by a set of generic processes (as shown in Figure 1). As the tool's functionality expanded, these generic processes helped accelerate development. We believe these patterns could be applied beyond COVID-19 rehabilitation, offering faster development and potential benefits in other areas of healthcare.

Acknowledgements

This research has been funded by Digital Futures (https://www.digitalfutures.kth.se/). The authors are also thankful to the four rehabilitation professionals at the Department of Rehabilitation Medicine in Stockholm at Danderyd University Hospital, Sweden, for their participation in the evaluation. Moreover, the authors thank the anonymous reviewers whose comments helped improve the text. The project has obtained an ethical approval from the Swedish Ethical Review Authority (Dnr 2023-05175-01).

References

[1] S.W., Hanson, C., Abbafati, J.G., Aerts, Z., Al-Aly, C., Ashbaugh, T., Ballouz, O., Blyuss, P., Bobkova, G., Bonsel, S., Borzakova, D., Buonsenso, Estimated Global Proportions of Individuals With Persistent Fatigue, Cognitive, and Respiratory Symptom Clusters Following Symptomatic COVID-19 in 2020 and 2021. Jama, 2022. 328(16): 1604-1615, (2022).

[2] World Health Organization (2021). A clinical case definition of post COVID-19 condition by a Delphi consensus, 6 October 2021. Available (2024-07-07) at: https://www.who.int/publications/i/item/WHO-2019-nCoV-Post_COVID-19_condition-Clinical_case_definition-2021.1. 2021

[3] K., Borg, H., Stam, Rehabilitation of post-Covid – 19 syndrome – once again a call for action! Journal of Rehabilitation Medicine 53, No 1. (2021). doi: 10.2340/16501977-2783

[4] K.M., Kelly, R., Anghinah, A., Kullmann, R.C., Ashmore, A.S., Synowiec, L.C., Gibson, L., Manfrinati, A.D., Araújo, R.R., Spera, S.M.D., Brucki, R.L., Tuma, Oculomotor, vestibular, reaction time, and cognitive tests as objective measures of neural deficits in patients post COVID-19 infection. Frontiers in Neurology, 2022: 13, 919596. (2022).

[5] eRehabCog, Danderyd Hospital. Available at: www.ds.se/erehabcog [Accessed 16 Aug, 2024]
[6] Cogmed (2023). Web site for Cogmed. (2024-07-07): https://www.cogmed.com/
[7] Vårdgivarguiden, Digifysisk vård, Region Stockholm. Accessed (2024-07-07): https://vardgivarguiden.se/it-stod/digitalisering/digifysisk-vard/
[8] J., Johansson, M., Moller, G., Markovic, K., Borg, Vision impairment is common in non-hospitalised patients with post-COVID-19 syndrome. Clinical & experimental optometry: journal of the Australian Optometrical Association. 2023:1-8. (2023).
[9] M. C., Möller, J., Johansson, G., Matuseviciene, T., Pansell, C. N., Deboussard, An observational study of trait and state fatigue, and their relation to cognitive fatigability and saccade performance. Concussion, 4(2), CNC62. (2019).
[10] E., Gustafsson, Internet-based cognitive rehabilitation for patients with mild cognitive impairment after acquired brain injury: A qualitative pilot study. (2019). Internal report (emma.gustafsson@sll.se)
[11] Online rehabilitation system for COVID-19 patients with long term cognitive problems, research project. Available at: https://www.su.se/english/research/research-projects/online-rehabilitation-system-for-covid-19-patients-with-long-term-cognitive-problems [Accessed 16 Aug, 2024]
[12] P., Johannesson, E., Perjons, Design principles for process modelling in enterprise application integration. Information Systems, 26 (3), Elsevier Science Ltd, pp. 165–184, (2001).
[13] E., Perjons, B., Wangler, J., Wäyrynen, R.-M., Åhlfeldt, Introducing a process manager in healthcare: An experience report, Health Informatics Journal, 11 (1), Sage, pp. 45–61. 25, (2005).
[14] B., Wangler, E., Perjons, R.-M., Åhlfeldt, Process oriented information systems architectures in healthcare. Health Informatics Journal, 9 (4), Sage, pp. 253– 265. 27, (2003).
[15] K.D., Cicerone, Y., Goldin, K., Ganci, et al. Evidence-Based Cognitive Rehabilitation: Systematic Review of the Literature From 2009 Through 2014. Arch Phys Med Rehabil. 2019;100(8):1515-1533. doi:10.1016/j.apmr.2019.02.011
[16] B., Ekman, H., Thulesius, J., Wilkens, A., Lindgren, O., Cronberg, E., Arvidsson, Utilization of digital primary care in Sweden : Descriptive analysis of claims data on demographics, socioeconomics, and diagnoses. International Journal of Medical Informatics 127. p.134-140, (2019). doi: 10.1016/j.ijmedinf.2019.04.016.