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Intelligent Customer-driven Solution for Orthopedic and Pediatric Surgery Care (ICory): Final Report

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INTELLIGENT CUSTOMER-DRIVEN SOLUTION FOR ORTHOPEDIC AND PEDIATRIC SURGERY CARE (ICORY): FINAL REPORT

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Summary <p>This report summarizes main activities and achieved results of the ICory project, a co-innovation project funded by Business Finland and carried out during 2018-2021. ICory aimed at 1) co-creating an intelligent patient-centric digital solution for orthopedic and pediatric surgery care journeys; 2) assessing impact of the developed solution from both medical, patient, and business perspectives; 3) and developing ecosystemic business model for speeding up companies' access to the international market. In ICory, the patient journey solutions were co-developed together with researchers, hospitals, and companies; effectiveness of the solutions were evaluated in two randomized controlled trials in Finland; Rehaboo! Exercise Game is being evaluated in a RCT in Singapore; a medicine delivery robot was developed and tested; research on business models was conducted; collaboration with three hospitals in Singapore and one Australian University was built. Results of the studies have been published in 27 scientific journal and conferences articles, and 2 doctoral dissertations were done during the project. The COVID-19 pandemic has affected functioning of the participating hospitals, delaying recruitment of patients and progression of the RCT studies. Analysis of the RCT data has started and the results will be published in several scientific articles after the project.</p>	
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1 Introduction

The social and healthcare services are going through a major renewal process in all over the world. Two main objectives, to produce the services more cost-efficiently and change them to be more patient-centric, are common to all healthcare service providers - regardless of how they are funded. Even though modern hospitals and care centers already have relatively well-developed information systems and databases, communication between patients, nurses, and doctors as well as the real empowerment of patients is inadequate and not fully supported by technology. Digitalization with new communication technologies, medical devices, diagnostic technology, machine learning, and gamification open new opportunities to empower patients, utilize remote connections, real-time data, and different sensors along a care journey between primary, secondary, and home care. The technologies, however, do not turn to the high-quality healthcare services without companies around the same business idea working together and with the patients and clinicians for better and coherent healthcare solution creation and adoption.

To answer these needs, a project called Intelligent Customer-driven Solution for Orthopedic and Pediatric Surgery Care (ICory) was set up and carried out during 2018-2021. The objective of the project was to 1) iteratively co-create an intelligent, next-generation patient-centric digital solution for orthopedic and pediatric surgery care journeys with the selected health ecosystems; 2) make impact analysis of the developed solution from both medical, patient, and business perspectives; 3) develop ecosystemic business model that helps build customer value and scale the solution to speed the companies' access to the international market.

The project was funded by Business Finland and coordinated by VTT Technical Research Centre of Finland Ltd (VTT). It included following partners from Finland: University of Oulu, Tampere University, Oulu University Hospital (OYS), Children's Hospital from Hospital District of Helsinki and Uusimaa (HUS), Buddy Healthcare, Near Real, Rehaboo!, Solteq, Triumph Health, Lenovo¹, BCB Medical Oy¹, Ticca Oy¹, and Johnson & Johnson¹. In addition, collaboration was built with three Singaporean hospitals: National University of Singapore (NUS), KK Women's and Children's Hospital (KKH), and National University Hospital (NUH). Collaboration was also built with an Australian university: RMIT University, Melbourne, Australia. The ICory process of co-developing and evaluating digital healthcare solutions is depicted in Figure 1.

This report summarizes the main activities and achieved results of the ICory project. First, development and evaluation of patient journey solutions for orthopedic and pediatric surgery are described. They are followed by activities in Singaporean hospitals, testing of Rehaboo! Exercise Game in Singapore, description of business model research, and development and testing of a medicine delivery robot in HUS. Finally, utilization and impact of the results and evaluation of the project are presented.

¹ Left the project before it ended

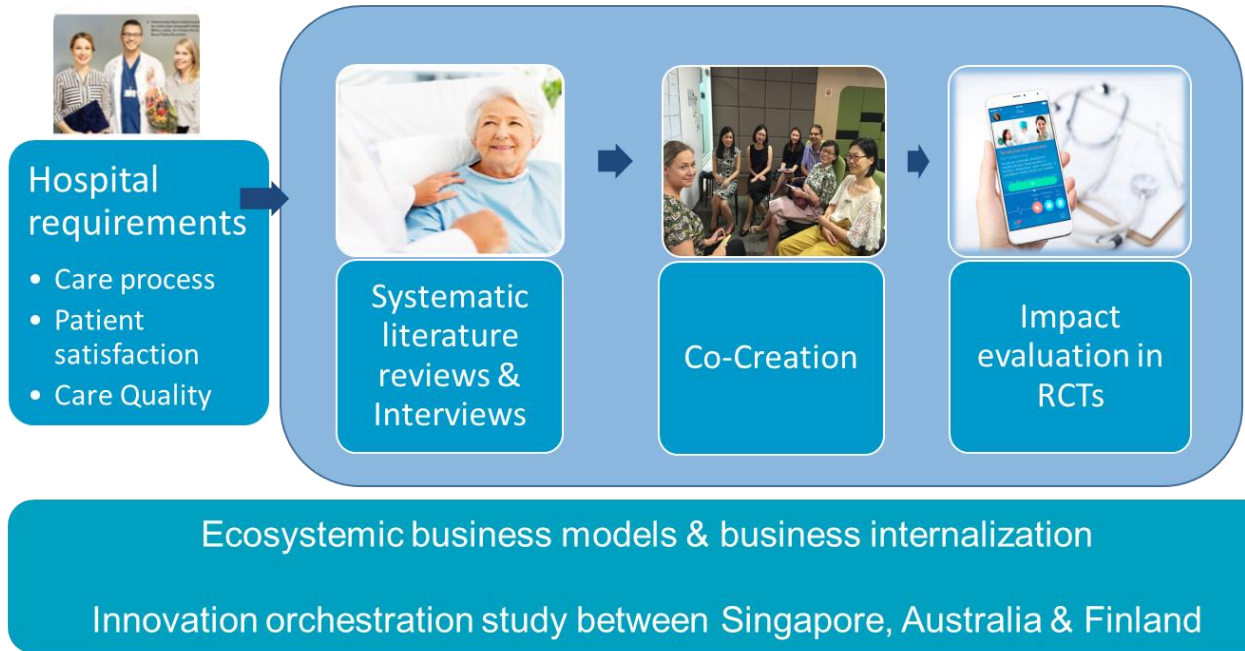


Figure 1. The ICory process for developing digital healthcare services. RCT, randomized controlled trial

2 Digital patient journey solution for orthopedic surgery patients

The digital patient journey solution for orthopedic surgery in adults was developed and its effectiveness was evaluated in close collaboration between the project partners.

2.1 The objective of the project

The aim of the project was to co-develop and evaluate effectiveness of the digital patient journey solution for orthopedic surgery patients. The solution covered the whole journey from home to hospital and back home. The aim of the project for OYS was to improve communication between the patient and the hospital staff. The goal was also to develop the patient's care path; increase safety; and improve the patient experience. For Buddy Healthcare, the objective of the project was to learn orthopedics care pathway process and identify the challenges it has and how digitalizing the process can help the patients and healthcare professionals in their daily life.

2.2 Description of the work

The work started by conducting a literature review and interviewing healthcare professionals and patients about total hip and knee arthroplasty care paths. The results from these studies have been published as scientific articles. Then, ICory solution elements were co-developed using methods such as prototyping, use case definitions, and analysis of interview data collected from healthcare professionals and patients. The developed patient journey solution consisted of a native app for patients and a clinician dashboard for health care professionals. The solution was based on an existing patient journey platform by Buddy Healthcare and high-definition audio and video solution by Near Real.

Buddy Healthcare configured digital care pathways for total hip and total knee joint replacement surgery. The pathways were based on a care process, previously identified in the ICory project. Contents of the care pathways were based on hospital materials and care protocol schedules. The app for the patients included all necessary information regarding the surgery, e.g., schedule and instructions for preparations and rehabilitation. There were also messaging and call functionalities for contacting a nurse. In addition to a normal workflow, Patient Reported Outcomes, Patient Experience Metrics, and Digital Capability questionnaires were added to the care pathways to collect information on the patients' recovery, care process, and patients' capabilities to use mobile technologies in their health-related issues.

Effectiveness of the developed patient journey solution was evaluated in a RCT. The research organizations and an orthopedic surgeon and a nurse from OYS designed the study. The RCT was conducted at OYS's joint replacement surgery unit, where the study nurse recruited study participants and performed their follow-up. VTT monitored the progression of the RCT. In total 69 patients were recruited and 63 completed the study. Due to delays caused by COVID-19, the data analysis was performed at the end of the project. The main findings will be presented in two scientific articles (one submitted, one under preparation). In addition, an article about the description of the concept framework for ICory digital patient journey

solution is under publishing process and another article about value-based healthcare will also be published in collaboration with RMIT University, Melbourne, Australia.

2.3 The main results

Hospital perspective (OYS)

Patients' experience of the new method was positive. Digital communication methods can improve communication between patients and the hospital. Digital solutions can also enhance a patient's care path.

Company perspective (Buddy Healthcare)

One of the main results for Buddy Healthcare was to learn and modify BuddyCare platform to conduct clinical studies. Several studies have been done and are ongoing with the knowledge learnt from the ICory project. Results from the clinical studies are still on process and are much waited to understand digital care pathway benefits for the patients and for the healthcare professionals.

Research organization perspective (VTT, University of Oulu, Tampere University)

The project compiled a description of the current orthopedic surgery journeys in OYS, including different phases, challenges, improvement possibilities, and used technologies. The patient journey solution was designed and implemented. The ecosystemic business models for patient journey solution were developed. Several scientific articles were published already during the project. The RCT was conducted successfully, even in the era of pandemic, and its main findings will be published in scientific articles during 2022.

3 Digital patient journey solution for pediatric surgery patients

The gamified patient journey solution for pediatric surgery was developed and its effectiveness was evaluated in close collaboration between the project partners.

3.1 The objective of the project

The aim of the project was to 1) characterize the perspectives and needs of health care professionals when developing a digital gaming solution for children and families in a pediatric day surgery; 2) describe the experiences and challenges of parents during a pediatric day surgery journey, and their needs and expectations for a digital gaming solution; 3) co-develop a patient-centric digital solution for pediatric day surgery journey from home to hospital and back home; and 4) evaluate effectiveness of the patient journey solution in a RCT.

3.2 Description of the work

The development of the gamified patient journey solution for pediatric surgery started with conducting and publishing a systematic literature review and meta-analysis on the effectiveness of web-based mobile health interventions in pediatric outpatient surgery. Health professionals' views on the needs for digital gaming solutions in pediatric surgery were collected in semi-structured, face-to-face interviews of 15 health care specialists in the New Children's Hospital, Helsinki. Parents' views were collected with a questionnaire survey from 31 parents. Additionally, the ICory project aimed at bringing gamified aspects to the patient journey solution. To achieve this goal, two systematic literature reviews on gamified solutions were conducted. This issue was also studied in a Masters' thesis which will be published shortly.

Triumpf Health provided their gamified patient solution to be used in the ICory project. Their solution offers children an informative, yet fun journey to empower them with skills and knowledge to help them develop. Triumpf Health has started from chronic illnesses and the mental burden related to disease management. In this project, the solution was utilized in pediatric surgery. Buddy Healthcare provided their existing digital solution to be used by the parents. The solution included all necessary information regarding the surgery, e.g., schedule and instructions for preparations and rehabilitation. In addition, all research questionnaires were delivered to parents through the solution. Solutions provided by Triumpf Health and Buddy Healthcare are shown in Figure 2. The work started with the existing solutions and those were updated based on the results from the co-development with hospitals, companies, and research organizations.

Finally, the RCT was planned to evaluate effectiveness of the gaming solution provided by Triumpf Health. Both intervention and control group received the Buddy Healthcare solution for delivering care information for parents. The RCT was conducted in the New Children's Hospital, Helsinki. Their study nurse recruited school-aged children coming to a day surgery procedure. VTT monitored the progression of the RCT. The COVID-19 pandemic delayed the recruitment process severely. It also had unexpected effects on the patient profile of the

pediatric day surgery unit. Previously, patients with ear, nose, or throat operations were common, however during the pandemic, they disappeared almost completely. This was due to better hand hygiene and keeping mildly sick children at home.



Figure 2. The gamified solution developed by Triumph Health (left) and the patient journey solution developed by Buddy Healthcare (right).

3.3 The main results

Digital solutions for pediatric day surgery journey should include support for preoperative, intra-operative, and postoperative information, care, and guidance. Digital gaming solutions can be used to help children and families to be better prepared for upcoming treatments and to support communication in different languages. A gamified mobile health intervention and a study protocol for the RCT concerning pediatric day surgery journey were described and published as a scientific article. COVID-19 caused notable delays and problems in recruitment, thus the RCT data analysis and reporting of results will be conducted after the project during 2022. One doctoral dissertation was done: Arja Rantala (November 2021): *Pelillinen mobiilisovellusinterventio kouluikäisten lasten päiväkirurgisella hoitopolulla (A gamified mobile health intervention for school-aged children in day surgery care).*

4 Collaboration with hospitals in Singapore

During the ICory project, collaboration was built with three hospitals in Singapore: KK Women’s and Children’s Hospital (KKH), National University Hospital (NUH), and Tan Tock Seng Singapore Hospital (TTSH). The studies in KKH focused on breast cancer and children neurosurgery, NUH focused on children day surgery, and TTSH focused on frozen shoulder and rotator cuff tear repair surgery. Similar to studies conducted in OYS and HUS, the studies in Singapore also included a co-design phase; modification of contents; pilots or preliminary studies, and they also aimed to carry out RCTs. One example of the collaboration with TTSH is presented in more detail in the next chapter of this report: *Rehaboo! Exercise Game*. The projects in Singapore were funded by local funding instruments. These studies were also hampered by the COVID-19 pandemic and difficulties in obtaining funding.

5 Rehaboo! Exercise Game

5.1 The objective of the project

Our objective in joining the ICory project was to participate in the research project with one of the key stakeholders (Oulu University Hospital, HUS new children's hospital or Tan Tock Seng Singapore Hospital (TTSH)), plus get direction and feedback from the University of Tampere Gamification group.

5.2 Description of the work

We gave our Rehaboo! Exercise Game, and its physical therapy tailored solution for Beta testing to the hospitals within the project, and are working on the Frozen Shoulder RCT study within TTSH.

5.3 The main results

The game is currently in use, and TTSH is applying for extra time to conclude the RCT during spring 2022. We have received a lot of feedback and have been co-creating the version for the physical therapy needs. Currently we are hoping for intermediate results within the final report, even if the main study is still going on.

6 Business model research

6.1 The objective of the project

One of the objectives of the project was to develop ecosystemic business models that help build customer value and scale the ICory solution to speed the companies' access to the international market. The developed solution was aimed at the better, personalized end user experience based on context-specific applications, data analytics and personal profiles.

6.2 Description of the work

The business model research was carried out in work package 5. In the work package we applied service-dominant logic and value co-creation through business model innovation within an ecosystem by utilizing an action research and case study methodology. The purpose of the chosen approaches was to bring the collective experiences and competences of the participant organizations and people together to co-create new knowledge and solutions, which in turn served as input for the business model development. In co-creation approach, iterative development activities, testing and feedback play an important role in introducing internationally scalable and sustainable solutions.

Our research approach was novel, since business models as a conceptual tool had rarely been applied in ecosystemic contexts. However, an increasing body of research has acknowledged the potential of business model concept as a boundary-spanning analysis tool. Based on an extensive business model literature analysis, we identified three key elements of ecosystemic business models: opportunity, value and advantage. Furthermore, we specified three key features that describe the arrangement and the dynamics of business ecosystems: business ecosystem structure, interaction between ecosystem actors and value configurations within the ecosystem.

6.3 The main results

The business model research resulted into several academic conference and journal publications and one doctoral dissertation was done about the business models: Julius Francis Gomez (August 2020): Exploring connected health business ecosystems through business models. The results have created direct benefit to the partner companies who have utilized the developed ecosystemic business models and the established international collaboration, and related networks in creating and realizing new business opportunities in both national and international markets. Furthermore, the research will in the long term provide indirect benefit to digital health sector companies in general, as the results provide valuable knowledge in creating competitive advantage.

7 Medicine delivery robot testing

7.1 The objective of the project

The initial object of the project was to do an AI-based solution to prioritize patients according to their patient data. This never happened since Solteq did not get access to any of the patient data, therefore there was no possibility to utilize a data lake solution for this purpose. However, during the project, it was agreed that scope change was needed. After the initial shutdown because of the covid situation, Solteq then got a possibility to test a new indoor logistic solution in a real hospital environment. Testing continues in HUS children's ICU, where the indoor logistic robot is delivering medicine daily. It was agreed that this will be the main objective for Solteq in this project. This does not overlap with other project partners.

7.2 Description of the work

Earlier project work was based on an idea that AI solution is used to mine data lake which has anonymized patient data. Idea was to find patterns and prioritize the case. A prototype solution was built but it was never used with real data, simply because Solteq had no access to it. Access to data was never granted and after this Solteq decided to propose a robotics-based solution that could be done during the project. Pilot to HUS children hospital was proposed initially, but it had to be postponed because of the covid situation. After the situation got better and access to the hospital environment was given, Solteq started to test a prototype robot in the neonatal intensive care unit. The purpose of the indoor logistic pilot was to gather enough information for the actual production version. Testing is still ongoing, even after the ICory project ended.

7.3 The main results

- Employee retention (+15k steps daily) is an issue that requires modern solutions
- Repetitive task that can be automated rather easily with robotics technology
- More business opportunities for Solteq Robotics afterwards
- Joint development done with design thinking principles together with the staff of HUS



Figure 3. Solteq medicine delivery robot prototype in HUS

8 Utilization and the impact of the results

Hospital perspective (OYS)

The results of the project will help to develop new operating models in the hospital environment. In the future, digital solutions will become more common and OYS will also consider the introduction of this type of operating model more broadly. The project can have significant implications for the promotion of patient-centered thinking in healthcare.

Hospital perspective (HUS)

The project provides new information on the needs of a gaming mobile health interventions for the day surgery pathway for school-age children. The information obtained from the project can be used to support the development of solutions and interventions.

Company perspective (Buddy Healthcare)

Results of the RCT will be very important for the company to the application for the new MDR medical device regulation. Results will be also very important for company to show benefits of digitalization of care pathways to patients and healthcare professionals.

Company perspective (Rehaboo!)

Currently (with Minna Pikkarainen) there is a plan to make a doctoral thesis on the study. Those results can then be utilized in further development of the Rehaboo! Active game to be used in physical therapy treatments, and especially in remote exercising, to make the exercising Fun, Empowering, and especially Measurable.

Company perspective (Solteq)

Solteq gained a completely new business sector because of this project. Solteq did not have access to the environment needed for testing and without the ICory project, it would have not been otherwise possible. Robotics solutions cannot be finalized or productized in lab environments. There is always a need for real-life places where robots are going to be working in future. Use cases can always be planned but nothing beats the actual environment and users. Healthcare professionals know their craft and robotics engineering teams cannot guess what is required from the robots in healthcare. This input comes from actual professionals.

Research organization perspective (VTT, University of Oulu, Tampere University)

The project increased knowledge on how to develop digital health services and conduct clinical research in cooperation with research organisations, hospitals, and companies. Collaboration between VTT and University of Oulu has continued in the Stroke-Data project which is also funded by Business Finland. Aim of the Stroke-Data is to co-create solutions for stroke prevention, diagnostics, and tertiary prevention. Stroke-Data has utilized experiences gathered during ICory, study plans and protocols, data management plans, and patient experience surveys. In total, 27 scientific journal or conference articles were published during the ICory project (literature reviews, need studies, business studies, RCT protocols). A material

package of published articles about the RCT in OYS has been delivered to four hospital districts (KHSHP, SATSHP, EPSHP, PHHYKY). The hospitals will utilize this package in their care process enhancement activities. Partner companies have utilized the developed ICory solution, ecosystemic business models, and the international collaboration, and related networks in creating and realizing new business opportunities in both national and international markets. Results of the RCT studies will be published as scientific articles. These will be valuable references for the companies involved in the project. Actors in healthcare sector can also utilize these results, when considering deployment and possibilities of digital patient journey solutions in their organisation.

9 Evaluation of the project: main positive things and things to improve

Hospital perspective (OYS)

OYS's joint replacement surgery unit has gained experience and knowledge of technological development process as well as cooperation with technological companies and other research units. Cooperation between users and companies is important already in the development phase of new applications and technologies. In this way, the usability of hardware and software is improved.

Hospital perspective (HUS)

The project helped the hospital in planning and taking new steps of digitalization of hospital processes and services. Integration of applications from external providers with the hospital ICT environment seems to be challenging. Working processes for integration and collaboration should be developed at the hospital end.

Company perspective (Buddy Healthcare)

Collaboration in the multidisciplinary project has been very important for the company to learn complexity of healthcare processes and challenges to evaluate and collect patient reported outcomes.

Company perspective (Rehaboo!)

The project has been very long, and the development has been thorough. We were at first disappointed for not being part of the HUS Children's Hospital project (apart from a very early stage paid pilot (it cost us 3.000€ to participate). But the final outcome with TTSH is very interesting. The structure changed quite a bit during the research project, but the outcomes seem to be very good. The main thing to improve would be the speed and being more straight forward within the research project. Waiting for the end results.

Company perspective (Solteq)

Positive things:

- Access to real hospital environment to test indoor logistics solutions
- Network of people from the healthcare sector
- Future possibilities in healthcare sector
- Knowledge about healthcare sector that would not been possible without the ICory project

Negative things

- Time, money, and work effort spent on healthcare data lake solution was futile and prototype solution could not be used in any other business case
- Solteq was not able to be part of the consortium's other business partners work since robotics was a completely separate solution from what other business partners were working on

Research organization perspective (University of Oulu)

Main positive things from the University of Oulu's perspective were the innovative co-creation-based project process, which enabled active and fruitful collaboration between all partners. Another benefit of this co-creative approach was that the ICory solution could be researched, developed and tested utilizing real hospital environments thus enabling both scientific robustness and practical value and relevance of the developed solution. This was further emphasized via active international collaboration. In terms of things to improve, the COVID-19 situation highlighted the importance of having a solid risk management plan and identified procedures to mitigate this type of prolonged risks. This is definitely a lesson learned for preparing future projects.

Research organization perspective (VTT)

Regarding main positive things, we had active and good collaboration between the partners with different backgrounds. We had common aims, partners had own roles, and they all worked together to achieve the aims. Conducting studies in a real hospital environment; active involvement of the companies; and collaboration with Australia and Singapore were also on the positive side. Regarding things to improve, the project had to be extended several times due to delays caused by the COVID-19. In addition, the General Data Protection Regulation (GDPR) came into force during the project, which caused extra work and delays in data management and ethical approval processes. However, learning to follow the GDPR in a real research project will benefit our future projects. The COVID-19 emphasized the need for proper risk management.