

Rehabnect – Infusing the Shoulder Abduction Rehabilitation Exercise with Ludic Elements

Rehabnect – Melhorando exercícios de Reabilitação de abdução de ombros com elementos lúdicos

Rehabnect - Mejorando el Ejercicio de Rehabilitación de abducción de hombro con elementos Lúdicos

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ABSTRACT

Keywords:

Rehabilitation; Exercise therapy; Experimental game; Technology

This paper details the development and evaluation of our rehabilitation game prototype *Rehabnect*. *Rehabnect* was created in collaboration with Nordsjællands Hospital in Denmark as a small-scale project that should investigate the possible benefits from infusing the shoulder abduction rehabilitation exercise with ludic elements. Based on interviews and domain-studies, two mini-games were designed around the shoulder abduction exercise and implemented using the *Microsoft Kinect* motion control sensor. *Rehabnect* was then evaluated with a small group of test patients, who participated in interviews and user testing sessions. The interviews revealed that most test participants found to a degree motivational benefits from utilizing *Rehabnect*. However, the test circumstances prohibited us from making any overall or general conclusions at this juncture. Nevertheless, we do feel that our design process and the game design resulting from said process may be helpful to other designers wishing to undertake similar projects.

RESUMO

Descritores:

Reabilitação; Terapia por exercício; Jogo experimental; Tecnologia

Este artigo detalha o desenvolvimento e avaliação de nosso protótipo jogo reabilitação *Rehabnect*. *Rehabnect* foi criado em colaboração com Nordsjællands Hospital, na Dinamarca como um projeto de pequena escala, que deve investigar os possíveis benefícios de infundir o exercício reabilitação abdução do ombro com elementos lúdicos. Com base em entrevistas e estudos de domínio, dois mini-jogos foram projetados em torno do exercício de abdução do ombro e implementado utilizando o sensor de controle de movimento da *Microsoft Kinect*. *Rehabnect* foi então avaliada com um pequeno grupo de pacientes de teste, que participaram de entrevistas e sessões de testes de usuário. As entrevistas revelaram que a maioria dos participantes do teste encontrado a um grau de benefícios motivacionais utilizando *Rehabnect*. As circunstâncias do teste nos proibiram de fazer quaisquer conclusões globais ou gerais neste momento. No entanto, nós sentimos que o nosso processo de concepção e design do jogo resultante de tal processo pode ser útil para outros designers que desejam realizar projetos similares.

RESUMEN

Descriptores:

Rehabilitación; Terapia por ejercicio; Juego experimental; Tecnologia

En este artículo se detalla el desarrollo y la evaluación de nuestro prototipo de juego de rehabilitación *Rehabnect*. *Rehabnect* fue creado en colaboración con el Hospital Nordsjællands en Dinamarca como un proyecto a pequeña escala que debe investigar los posibles beneficios de la infusión de la abducción del hombro ejercicios de rehabilitación con elementos lúdicos. Con base en entrevistas y estudios de dominio, dos mini-juegos fueron diseñados en torno al ejercicio de abducción de hombro y aplicarse mediante el sensor de control de movimiento *Kinect* de *Microsoft*. Entonces *Rehabnect* se evaluó con un pequeño grupo de pacientes de prueba, que participaron en las entrevistas y sesiones de pruebas de usuario. Las entrevistas revelaron que la mayoría de los participantes en la prueba encontró que un grado de motivación beneficios de la utilización de *Rehabnect*. Las circunstancias de la prueba nos prohibido hacer conclusiones globales o generales en esta coyuntura. Sin embargo, sentimos que nuestro proceso de diseño y el diseño del juego resultante de dicho proceso pueden ser de utilidad para otros diseñadores que deseen emprender proyectos similares.

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INTRODUCTION

Nordsjællands Hospital is situated in the vicinity of the city of Hillerød in Northern Zealand in Denmark. As part of its services, Nordsjællands Hospital treats patients suffering from physical damages to their motor apparatus – including acute traumas (e.g. bone injuries) and chronic disorders such as degenerative joint disease). As part of their treatment, patients enter into a rehabilitation program. Individual fitted rehabilitation influences how quickly the patient can reacquire previous levels of functional ability. The rehabilitation process generally consists of two stages: training at the hospital under the supervision of physiotherapists, followed by training at the patient's home. At hospital discharge, the patient is typically instructed in how to continue with specific exercises, often supplemented by written materials such as a pamphlet.

Rehabilitation can be considered successful if the patient achieves the prior or the expected level of motor proficiency in the anticipated time. However, it is well known that the motivation to actually do the exercises can diminish over time and that patients often express the need for support from a physiotherapist and other patients⁽¹⁾. Loss of motivation may decrease patient training compliance and may thus result in a patient with a chronic need for government benefits. This is, in a broad manner of speaking, both costly for the individual and costly for the society.

Physiotherapists at Nordsjællands Hospital revealed in initial interviews conducted with them as part of this small-scale project, that they also recognize the loss of motivation as a potential risk to the effectiveness of the rehabilitation process.

Therefore, the goal of this small-scale project was to investigate whether or not infusing one of the rehabilitative exercises used at Nordsjællands Hospital with gameplay mechanics could improve motivation for patients. *Rehabnect* should be seen as an exploration of the effects of combining a specific rehabilitation exercise with ludic elements.

The *Rehabnect* prototype was developed as part of a 3-month student project at the IT-University of Copenhagen in the spring of 2011 as part of the M.Sc. course *Persuasive and Serious Games* under the supervision of Associate Professor Rilla Khaled.

BACKGROUND

Motion Sensor Rehabilitation

The use of motion-control sensors for rehabilitative purposes has been described in a number of studies utilizing either the *Nintendo Wii* system, the *Microsoft Kinect* system (abbreviated as *Kinect*), other commercially available motion sensor systems or 'home-made' sensor systems. Using the *Nintendo Wii* system Decker et al.⁽²⁾ investigated wrist rehabilitation for stroke patients. Hsu et al.⁽³⁾ studied the introduction of a *Wii* bowling game at a long-term care center. Finally Dimovska et al.⁽⁴⁾ successfully explored whether procedural content generation could be used to automatically create new level content for a rehabilitative *Nintendo Wii* game based on the performance of patients

with leg injuries while playing. All three studies found that using the *Nintendo Wii* was beneficial for the rehabilitative process, especially in terms of motivation.

By utilizing their own full body motion capture system for motor rehabilitation, Schönauer et al.⁽⁵⁾ successfully integrated their sensor into a game engine in order to create rehabilitation games. In their follow-up study, Schönauer et al.⁽⁶⁾ then combined the *Kinect* with their full body motion capture system and created a rehabilitation game for patients with chronic pain. Using the *Kinect* on patients with neurological disorders Lange et al.⁽⁷⁾ developed and assessed an interactive game-based rehabilitation tool. In a follow-up study Lange et al.⁽⁸⁾ went on to use the *Kinect* to create a rehabilitation game based on balance exercises. Hwang et al.⁽⁹⁾ studied the use of the *Kinect* with the aim to optimize the rehabilitation process and shorten the rehabilitation time for stroke patients. Changa et al.⁽¹⁰⁾ conducted a pilot study with young adults to test a *Kinect*-based rehabilitation system for motor impairment, showcasing the usage of the *Kinect* in connection with rehabilitation of young people. In a study, Da Gama et al.⁽¹¹⁾ demonstrated that digital feedback from the *Kinect* could help patients conduct motor rehabilitative exercises and encourage them at the same time. The beneficial effects found from employing the *Nintendo Wii* for rehabilitation purposes, were also found in the studies using the *Kinect* or 'homemade' systems.

In their in-depth overview of the main research done into using motion-control systems for rehabilitation and exercise in general, Taylor et al.⁽¹²⁾ described some of the above results as promising for improving the rehabilitation process for patients.

Rehabnect is similar to the above-mentioned efforts, as it too attempts to combine physical rehabilitation with the usage of motion-control sensors. Compared to these previous efforts, we think *Rehabnect* differentiates itself in its approach. Generally speaking the abovementioned research have taken a top-down approach by focusing on developing a game suitable for general play and exercise by rehabilitation patients. Whereas *Rehabnect* takes a bottom-up approach by focusing on building a game around a particular rehabilitation exercise used by patients as part of their treatment – in this project the shoulder abduction exercise.

The Shoulder Abduction Rehabilitative Exercise

The shoulder abduction exercise is a rehabilitative exercise used in the rehabilitation regimes for patients suffering from ailments such as frozen shoulder (adhesive capsulitis of shoulder), a broken arm and other motor apparatus damages. The exercise itself consists of lifting your arm up from the side of the body and then down again, while holding a rubber band in your hands that gets stretched out as the arm is lifted (see Figure 1). The physiotherapists at Nordsjællands Hospital, based on the patient's physical well-being, do not always require the usage of the rubber band for the exercise.

The selection of the shoulder abduction exercise was done in collaboration with the physiotherapists at Nordsjællands Hospital, because of its usage at the hospital. The exercise was also chosen because of its motion-sensor

friendly nature. From a technical standpoint, the shoulder abduction exercise appeared to be a good fit for capture by a motion-sensor as the patient could do the exercise perpendicular to the surface normal from the sensor's sensing surface. Furthermore, we chose to focus on a single rehabilitation exercise, due to the time constraints surrounding the project. It should also be noted that *Rehabnect* was designed to support the shoulder abduction exercise both when a rubber band is used and when it is not used by the patient.

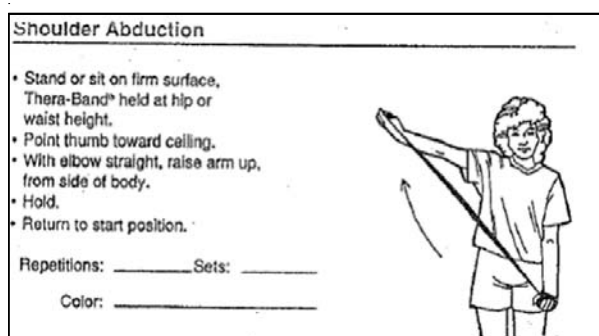


Figure 1 - The Shoulder Abduction Exercise. Source: Printed material from Nordsjællands Hospital.

REHABNECT

Rehabnect was realized as a functional rehabilitation game prototype running on a Windows PC. The prototype consists of two mini-games and a progress-tracking system. The prototype was built upon a technical foundation consisting of the *Kinect* motion-sensor, the *OpenNI PC Kinect* driver, the *Microsoft XNA Framework* and the *C# programming language*.

Technical Foundation

1) Motion-Sensor Selection

Two overarching criteria guided over our selection of motion-control sensor for the project – the sensor should be commercially available and it should be controller-free. A commercially available sensor would make longer term testing with multiple patients easier compared to a ‘home-made’ sensor constructed by the authors, as no extra time would be required to build multiple new sensors. Controller-free should be understood in the sense that the sensor itself does not require any kind of remote control to function. Compared to a motion-sensor requiring external peripherals, a controller-free sensor should be able to support more groups of rehabilitation patients, since using a controller requires a higher level of physical motor proficiency than not using a controller.

Based on these two criteria we ended up selecting the *Kinect* as our motion-sensor for the project. Another commercially available motion-control sensor, the *Nintendo Wii*, was not selected due to it requiring the usage of the *Wii Remote* peripheral to operate⁽¹³⁾.

2) Software Foundation

To operate the *Kinect* from a *Windows PC* required using the *OpenNI PC* drivers from *PrimeSense*, as no official PC drivers from *Microsoft* were available at the time (spring 2011).

The prototype itself was constructed using the *C# programming language* and the *XNA Framework* from *Microsoft*.

User Interface

1) General Interface

When interacting with the prototype the patient was presented with two general views shown side-by-side – the game-view and the sensor-view (see Figure 2). The game-view takes up the left half of the screen and shows all the interactive content of the prototype (menus, the two mini-games etc.). The sensor-view takes up the right half of the screen and shows what the *Kinect* sees and whom it currently tracks. The person being tracked appears highlighted with a green or red color.

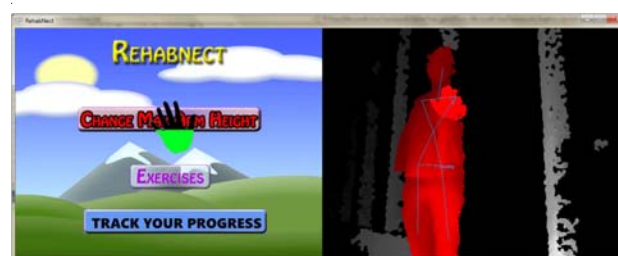


Figure 2 - The game-view on the left and the sensor-view on the right.

2) Interacting with the prototype

To facilitate peripheral-less menu navigation of the *Rehabnect*, patients use one of their hands (the one closest to the *Kinect*) to move a pointer around the screen in order to select which menu to enter. Menus are selected by hovering the pointer over the menu in question for a few seconds.

All mini-game interactions are done by doing the shoulder-abduction exercise.

The Two Mini-games

For *Rehabnect*, two different mini-games were designed around the shoulder abduction exercise – the sunflower mini-game (see Figure 3) and the catapult mini-game (see Figure 4).

Before any of the two mini-games begin, the patient is first instructed in how to do the shoulder-abduction exercise (see Figure 6). In order to start either of the mini-games the patient must do the shoulder-abduction exercise correctly once.

1) The Sunflower Mini-game

The goal of the sunflower mini-game is to grow as many sunflowers as possible by doing the shoulder abduction exercise. Every time the patient does the exercise, a water-pump visible in the game-view will begin to fill a balloon with water. After doing the shoulder abduction exercise two times, the balloon will float away from the pump, and shortly thereafter it will burst, thus spilling water on the ground, where a sunflower will begin to grow. The sunflower will continue to grow as more water-balloons are made until it grows too large to fit the screen – when this happens the sunflower is removed and a counter in the upper-left corner will increase by one, showing how many sunflowers that has been grown

in total. The game has no enforced end state and continues until the patient feels she or he has grown enough sunflowers.

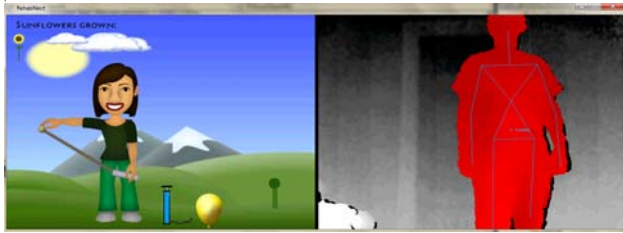


Figure 3 - The Sunflower mini-game.

2) The Catapult Mini-game

In the catapult mini-game the goal is to score as many points as possible by winding up and firing a catapult, all while trying to hit a target moving back-and-forth across the top of the screen. A cross hair in the top of the screen shows where the catapult is aimed. The goal then becomes a matter of timing the firing of the catapult to when the moving target moves into the cross-hair. The catapult is wound up by doing the shoulder-abduction exercise twice. When the catapult is wound up, it is fired by doing the shoulder abduction exercise one more time.



Figure 4 - The Catapult mini-game.

Digital Feedback

When interacting with the prototype the patient receives digital feedback based on her or his actions in a number of different ways – ways found in the menu-system and in the two mini-games.

1) Menu selection digital feedback

To interact with the menus, the patients move a hand-pointer around the screen by using their own hands. Selection is done by hovering the hand-pointer over the menu in question for a few seconds. Digital feedback is provided on the menu selection process by letting the hand-pointer gradually change color from black to green (see Figure 5).

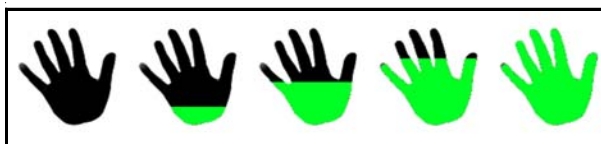


Figure 5 - Digital feedback for the menu selection process.

2) Mini-games digital feedback

In the mini-games there are two ways the patient receives digital feedback based on how well she or he is

performing the shoulder-abduction exercise - these two ways are the digital trainers and the motivational messages.

Digital Trainers

The prototype includes a digital trainer that is configurable to be either a female or a male. These digital trainers serve the dual purpose of giving instructions and guidance to the patient. At the beginning of each mini-game, the patient is instructed in how to properly perform the shoulder abduction exercise by the digital trainer. The digital trainer demonstrates the shoulder abduction exercise besides a textual description of it (see Figure 6). The mini-games do not begin until the patient has done the exercise correctly once.



Figure 6 - The digital trainer giving instructions.

In the mini-games themselves the digital trainer guides the patient towards the next step to perform of the shoulder abduction exercise – i.e. whether to lift one’s arm or to lower it. The digital trainer does this guiding by showing the body pose that the patient must mimic by doing the next step of the exercise. Every time the patient has carried out the next step of the shoulder abduction exercise correctly, the digital trainer glows green, thus providing feedback based on the patient’s performance (see Figure 7).



Figure 7 - The digital trainer glowing green after the patient has correctly matched the body pose of the trainer.

Motivational Messages

While playing the game the patient will receive motivational messages (e.g. “Good!”, see Figure 8) after having done the shoulder abduction exercise correctly every 10 times.



Figure 8 - Motivational message displayed doing the Sunflower mini-game.

Progression Tracking

Rehabnect also contains a simple progression tracking system, which keeps track of how high the patient has been able to lift her or his afflicted arm. Data collected is accessible from the “Your Progress”-menu (see Figure 9).



Figure 9 - The progress progression screen.

Technical Limitations

Our choice of the *OpenNI Kinect* driver did sadly bring one major technical limitation to our prototype, evident in its use of a so-called calibration pose required to be able to properly track people. In order for the *OpenNI Kinect* driver to track a patient, she or he first needs to hold a specific body-pose – when the *Kinect* then has registered the patient, the patient can move freely while being tracked (see Figure 10).



Figure 10 - The digital trainers showing the calibration body pose the patient has to match in order to start *Rehabnect*.

Another technical limitation is the fact that the *OpenNI Kinect* driver do not support the *Kinect* microphone, thus making the use of voice commands etc. impossible. Because of the lack of voice-commands, the patient must have one arm functioning well enough to comfortably navigate the menu-system.

DESIGN PROCESS

During the design process we entered into a close collaboration with the physiotherapists at Nordsjællands Hospital and some of their patients, who were undergoing rehabilitation using the shoulder abduction exercise. Our design process was structured after Lövgren and Stolteman's⁽¹⁴⁾ concept of the three overlapping meta-phases called the Vision-, Operative Image- and Specification phase. In the initial Vision phase, we explored the problem- and solution-space through interviews and the use of the participant observation method⁽¹⁵⁾. The Vision phase was followed by the Operative Image phase, in which we began to refine our initial ideas from the Vision phase through prototyping and interim testing.

Lastly, in the Operative Image phase the final version of *Rehabnect* was developed and tested.

The Vision Phase

During the Vision phase we conducted interview and participant observation sessions in order to explore the problem- and solution-space surrounding the usage of the shoulder abduction exercise at Nordsjællands Hospital.

1) Domain Expert Interviews

The interviews we conducted with some of the physiotherapists employed at Nordsjællands Hospital, i.e. the domain experts, introduced us to the rehabilitative procedures and practices at the hospital. The physiotherapists had some experience in using motion-control systems for some of their patients for the on-site rehabilitation – the *Nintendo Wii* and its *Wii Fit* game. Based on their experiences with the *Nintendo Wii*, the physiotherapists found the usage of motion-sensors for rehabilitation promising. The physiotherapists also introduced us to the main problem they faced from their patients – motivation, i.e. to keep their patients motivated throughout the complete rehabilitation process.

The patient motivation problem is typically not prevalent during the rehabilitation that takes place at the hospital under the guidance of a physiotherapist, but rather at the patient's home after discharge. At hospital discharge patients are instructed in what exercises, they should do at home through pamphlets. Some patients have weekly or monthly check-ups at the hospital, where physiotherapists will check on the patient's progress. It is at these check-ups that the physiotherapists have heard from the patients about the problem of keeping oneself motivated enough to do the rehabilitation exercises at home. The physiotherapists' assessment was that less motivated patients results in lower patient compliance, and thus in a longer rehabilitation period, which may in the worst-case result in a patient with chronic disabilities.

The physiotherapists pointed out the need for both short-term and long-term motivation for the patients at home. Short-term motivation in regards to when the patient is actually doing their exercises, so that they are kept motivated to keep going for as long as possible, and do not get bored or otherwise distracted – in other words are kept in the ‘moment’ for as long as possible. Long-term motivation in regards to making the patient continue to do their daily rehabilitation exercise over a long period of time e.g. several weeks or months.

Another point the physiotherapists made in the interviews was that two of the most important things to remember when during rehabilitative exercises are that patients do their exercises correctly and secondly that patients should not overwork their bodies. Patients stressing their bodies by doing “too much too fast too soon” through too intense exercise limits the benefits from the rehabilitation process.

2) Patient Interviews and Patient Participant Observation

We were also given the opportunity to interview two

of the patients that were undergoing rehabilitation at Nordsjællands Hospital, since we wanted to get their perspective on the motivational problems.

One of the possible demotivating factors highlighted by the patients was the lack of feedback and guidance when doing exercises alone compared to doing exercises at the hospital, where the physiotherapist is there to give immediate feedback on the patient's performance.

Another point the patients made was that they would over time find the rehabilitative exercises repetitive and in the end cumbersome, due to their often simplistic nature. This feeling of repetitiveness would, combined with a lengthy rehabilitation process, leave some patients with a hopeless attitude, as they could not see any immediate improvements.

Two participant observation sessions were conducted, in which two patients were studied doing their rehabilitation exercises with a physiotherapist as part of their monthly check-up. The two participant observation sessions helped us become more familiar with the interaction and feedback between physiotherapist and patient during exercises.

The Operative Image Phase

Towards the end of the Vision phase a few things were clear to us. First of all, the developed solution should attempt to motivate the patient on both a short-term and long-term basis. Secondly, the developed solution should attempt to capture parts of the feedback that the patient receives from the physiotherapist when doing exercises at the hospital. Thirdly, the developed solution should not stress nor push the patient to do the exercises in an intense manner, so the rehabilitative benefits are diminished. Thus, motivation and feedback were the focus in the operative image phase, where we prototyped and tested our initial ideas.

1) Motivating the patient as a player?

How to motivate a player to keep playing has been

the focus of many academic studies and game developers in general. The classic flow-model by Csikszentmihalyi⁽¹⁶⁾ has served as the basis for many studies. For instance, Sinclair et al.⁽¹⁷⁾ looked into adapting the flow-model for physical exercise games by extending it into a dual-flow model (see Figure 11).

However, we feel that neither the flow-model nor the dual-flow model is a very good fit for rehabilitation patients due to a number of reasons. By design, rehabilitation exercises are simple in nature in order to avoid putting unnecessary stress on the patient, and to only focus on the particular body part that needs rehabilitation. In other words, the rehabilitation exercises themselves are not challenging per se. The challenge aspects of doing rehabilitation exercises are found in the fact that the patient does not have full body faculty, due to the damage to her or his motor apparatus. However, as the physiotherapists at Nordsjællands Hospital made clear to us, you do not want to push the patient's body too far, as you then risk doing more harm than good in respect to the rehabilitation. This means for the dual-flow model that the challenge level and intensity-level were fixed in our project. The rehabilitation-game must cater to patients that are at different points in their rehabilitation process. Therefore, when it came to the design of the motivational aspects of *Rehabnect*, we tried to tackle it using another approach than the dual-flow model.

2) Motivating the Patient in Rehabnect

In *Rehabnect* we set out to motivate the patient in both a short-term and long-term manner. Short-term motivation focusses on making patients keep doing their exercises for as long as their bodies allows it, when they have begun a training session. Long-term motivation focusses on making the patient keep doing their exercises from week to week, i.e. to keep doing the rehabilitation exercises throughout the whole rehabilitation process.

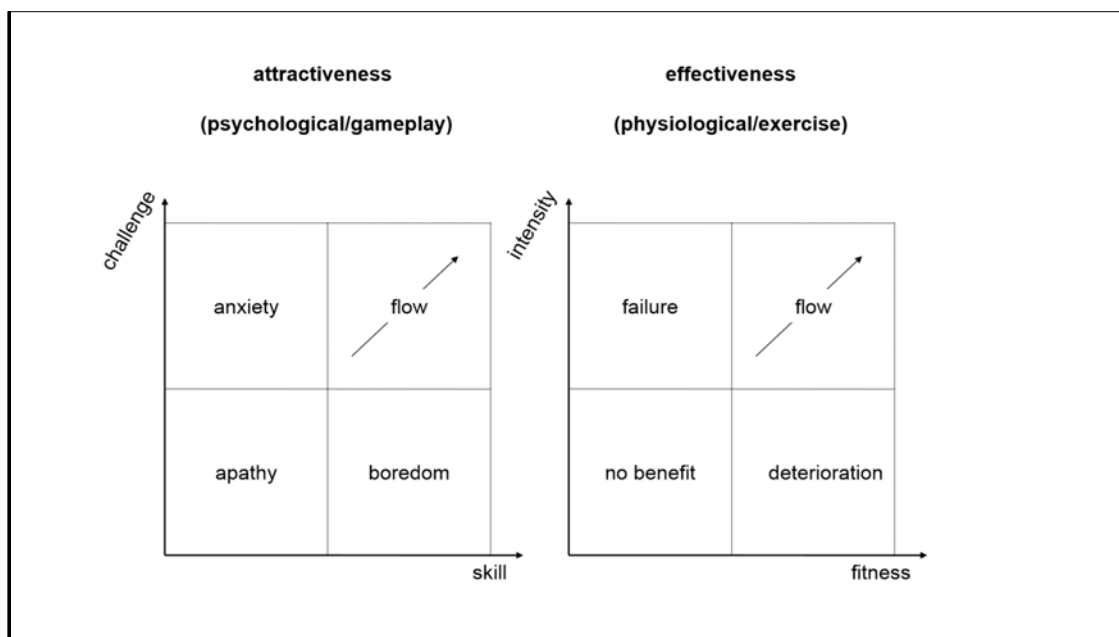


Figure 11 - The dual-flow model for exergames by Sinclair et. al.. Image reproduced from⁽¹⁷⁾.

Short-term motivation

We attempt to achieve short-term motivation through what we denote as motivation through distraction and motivation through compliment.

Motivation through distraction focusses on making patients forget that they are doing rehabilitation exercises and instead make them focus on that they are doing something else.

In the sunflower mini-game the patient, instead of thinking that she or he is doing the shoulder abduction exercise, should think that she or he is growing sunflowers by using the water-pump to fill up balloons. To reinforce the sunflower distraction the exercise action done in the real world by the patient corresponds to the action done in the mini-game. When the patient moves her or his arm up, the water pump on screen goes up – when the arm is moved down so does the water pump. At the end of a training session with the sunflower mini-game, the patient should be thinking about how many sunflowers were grown, instead of thinking of how many times the shoulder abduction exercise was done.

In the catapult mini-game the patient should focus on how many points she or he has accumulated by first winding up and then firing the catapult on the screen. Similar to the sunflower mini-game, we attempt to establish some kind of correspondence between the exercise action and the game action. Every time the patient completes a part of the shoulder abduction exercise (i.e. moving arm up or down) the catapult becomes more wound up – in other words, the patient's action corresponds to using a winch.

Motivation through compliment refers to the usage of messages to motivate the patient to continue the current exercise session. In *Rehabnect* the motivational messages serve as a pat on the back for the patient. The motivational messages are also an attempt to capture some of interactions between patient and physiotherapist we witnessed during the participant observation session.

Long-term motivation

We attempt to achieve long-term motivation through what we denote as *motivation through progression*. Motivation through progression focusses on motivating patients by giving them the means to track their own rehabilitative progress over longer periods of time. In *Rehabnect* the progression tracking systems attempts to achieve motivation through progression by presenting data on how much the patient has been able to lift her or his arm on a week-to-week basis.

Providing the Patient with feedback

Rehabnect provides feedback to the patient based on her or his actions mainly through the digital trainers, but also through the menu-system.

a) The Digital Trainers

The digital trainers are our main attempt to capture the interaction between physiotherapist and patient during hospital rehabilitative training. The digital trainer both demonstrates and guides the patient in doing the shoulder abduction exercise. While we recognize that the digital

trainer cannot replace the physiotherapist, we think the digital trainer should prove to be an improvement in terms of motivation over the rehabilitation pamphlets patients receive when being discharged.

b) Menu-feedback

The menu and its interaction was designed to be peripheral-less. When designing the interaction we looked for inspiration on how *Microsoft* designed the user interaction for using the *Kinect* on the *Xbox 360* video game console. The overarching principle we tried to adhere to was that user interaction should first and foremost be peripheral-less – i.e. the patient should be able to operate the prototype with only her or his body and nothing else.

c) Prototyping the Feedback systems

To find the right level of digital feedback to provide the patient with, we went through numerous prototypes of the different feedback systems. Originally, in the menu-system, patients would just move a standard mouse cursor around the screen. However, most of the patients who tested the prototype had trouble understanding when they had held the cursor long enough over a menu to select. Therefore, the mouse cursor was replaced by the filling hand symbol.

In the mini-games the digital trainers did not originally glow green when the patient had executed the next step of the shoulder abduction exercise correctly. Some of the test patients were unsure when they had done the next exercise step correct. Thus, the green glow was introduced to the digital trainers.

The Specification Phase

At the end of the operative image phase, we had a clear idea of what the final design of *Rehabnect* should look like, and hence the majority of the specification phase was used on realizing this design. Furthermore, time was also spent on finalizing the visual design, whose main goal was to establish a tranquil and non-stress atmosphere.

EVALUATING REHABNECT

Originally, we had planned to let patients undergoing rehabilitation treatment borrow a *Kinect* and a PC with *Rehabnect* installed on and test it at home, but due to the time constraints surrounding the project, this was not possible. Instead, testing took place in a recreated hospital setting with test patients using *Rehabnect* for a single rehabilitation session. Throughout the testing sessions we made use of the think-aloud method as described by Lauesen⁽¹⁸⁾. After each test session, a follow-up interview was conducted with the test participant.

Overall, six people participated in our testing of *Rehabnect*. At the beginning of each test session, participants were very briefly introduced to *Rehabnect* (no hints concerning operating the prototype were given) and its mini-games. Test participants were then instructed to play the game for as long as comfortable possible, i.e. until body fatigue would set in.

Overall speaking, three of the test patients had a

favorable view of *Rehabnect* and its short-term motivational potential. These test participants had found their rehabilitation session more engaging and motivating compared to training sessions at home. However, when asked to compare *Rehabnect* to training sessions at the hospital, all six of the test participants preferred the training sessions with the physiotherapist.

However, not all test results were positive. Two of the test patients had great trouble starting *Rehabnect* due to the technical limitation of the calibration pose. For these test participants it was simply not possible to match the calibration body pose. We did find a work-around by letting one of the authors of this paper start *Rehabnect* by doing the calibration pose and then stepping out of the *Kinect*'s field of view, but this 'solution' is not viable in a patient's home. Furthermore, five of the test patients had initial difficulties in learning to navigate the menus using their hands. Nevertheless, after spending some time getting used to controlling the menus the test participants managed to use it.

With these test results, it is hard to say anything conclusive about the motivational capabilities of *Rehabnect*. The six test patients only tested *Rehabnect* during a single session, which makes it tough to conclude whether it simply was the fact that using the prototype was different to their usual routine or the prototype itself that was the reason for their reception of *Rehabnect*. Furthermore, the small number of testers also makes it hard to draw any general conclusions concerning the motivational effectiveness of *Rehabnect*.

FUTURE IMPROVEMENTS

A number of things should be improved for future iterations of *Rehabnect*. From a technical point of view, *Rehabnect* should primarily be updated to use the official *Microsoft Kinect* drivers to remove the troublesome calibration pose. Another benefit from using official *Kinect*

drivers would be the facilitation of voice control, which could be used as an alternative to the hand controlled menu. Looking further ahead from a technical perspective, *Rehabnect* should be updated to utilize the upcoming new version of the *Kinect* for PC.

From a design perspective, *Rehabnect* should be tested by patients over a much longer period of time at home to truly determine the motivational benefits, short-term and long-term, from *Rehabnect*. Furthermore, *Rehabnect* should be expanded to support other rehabilitation exercises than the shoulder abduction exercise.

CONCLUSION

Even though the test results leave things to be desired, the project can in some regards be considered a success. We successfully employed Lövgren and Stolteman's concept of the three overlapping design meta-phases to design and implement a functional prototype that was usable by test patients. We did furthermore manage to test *Rehabnect*, and while the test patients did not provide enough data to claim the motivational success of *Rehabnect*, they did on the other hand not provide enough data to disavow the motivational benefits either. However, to be considered an overall success, this project will need more extensive testing to map the motivational benefits (if any) of *Rehabnect*. However, in spite of these results we encourage other designers to build upon our pragmatic experiences from the design process behind *Rehabnect*.

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