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A game-based approach for motoric stroke rehabilitation – defining the requirements

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Abstract: The global phenomenon with an increased percentage of older adults is clearly identified in the Mid Sweden region. With a population that is older than the average, the need for medical care and rehabilitation is also higher. All diseases have their specialised treatments and rehabilitation requirements, and this study has a focus on defining requirements for game-based motoric stroke rehabilitation. The important research question to answer was: How might a game-based approach to motoric stroke rehabilitation support the idea of independent living?

This study was carried out as a Requirement-Focused Design Science project, with the aim to define requirements for a stroke rehabilitation testbed. Requirements have been outlined with the Design science idea of asking the experts to explain their predictions of what they think will produce the effects. Eight domain experts with different professional roles were interviewed to obtain a multi-stakeholder perspective on technology enhanced and game-based stroke rehabilitation. Patterns and themes in the interview answers created categories in a thematic analysis. Furthermore, the concept was discussed with research colleagues with rich experience of e-health.

All of the interviewed experts had a surprisingly positive attitude toward the game-based approach, but with the strong recommendation of an individualised rehabilitation schedule. There are large variations in both the rehabilitation needs and the stroke patients' digital skills. An interesting comment from one of the informants was to involve dancing activities, as a complement to the game-based rehabilitation. Out of the three discussed stroke rehabilitation categories: cognitive, motoric and speech rehabilitation, motoric stroke rehabilitation seems to be the one with the highest potential for a game-based approach to support independent living. The outlined requirements could be an important part in the future implementation of a testbed for stroke rehabilitation

Keywords: Game-based learning, Game-based relearning, Stroke rehabilitation, Motoric stroke rehabilitation, Game-based stroke rehabilitation

1. Introduction

The percentage of older adults with chronic diseases increases and with a higher need long term rehabilitation. According to the population projections from Swedish Central Bureau of Statistics (SCB), in next 10 years, the population of people aged 80 or older will increase up to 50 present (SCB, 2018). Because of that constantly increasing demographic change, the healthcare providers are facing some serious challenges and the situation will become even more critical in the future (Fischer et al., 2014). On the other hand, most of elderly people like to stay in their home environments and they usually have an urge to live independently (Ahmad & Mozelius, 2019).

As highlighted by Juul (2010), the world-wide popularity of games like Nintendo Wii, Guitar Hero, and casual games like Candy Crush Saga has increased the number of regularly gamers. The typical gamer is no longer a young male playing so called 'hardcore games' (Juul, 2010), and the average age of digital gamers has definitely increased. Game-based learning is a well-established area (De Freitas, 2006) and the purposeful use of games is spreading in to new domains. A type of games that have been tested with promising result in health care for older adults are exergames (Van Diest et al, 2013). Exergames should by definition involve physical activities and break the tradition of digital gaming associated with a sedentary lifestyle.

Stroke patients have special needs (Ahmad, Mozelius & Ahlin, 2019), and are not always able to use the standard interfaces in commercial-of-the shelf games (Wiemeyer & Kliem, 2012). Using games for stroke rehabilitation also looks like a promising concept to stimulate patients' engagement (Burke et al, 2009). This study investigated the idea of using a mix of casual games and exergames to support the idea of joyful rehabilitation and independent living for stroke patients. An interesting concept for balance exercises and motoric rehabilitation of upper limbs for stroke patients is to use Kinect for motion sensitivity (Lange et al., 2011; Oh et al., 2012).

Stroke, in its initial phase, is treated in emergency care and with immediate thoughts on how to rehabilitate the patient. After the emergency treatment, the rehabilitation starts, and it is founded into the patient's condition and wishes for a better life (Dimaguila et al., 2018) and society's goal of a better life and health (UN, 2019). Since stroke is a lifelong condition, the rehabilitation has to be carried out throughout everyday phases of life, including the clinical and non-clinical environment. Combining the clinical and non-clinical environment and casual games or exergames with supervised everyday stroke rehabilitation requires that the hardware and software are easy to install, use and maintain for the patients (Deutch et al., 2011), as well as the previously mentioned specially designed interfaces. Other requirements for the stakeholders are the caregivers and people near the patient. General requirements for the caregiver is to have access to see which and how their patients conducted assignments for development purposes and the opportunity to adapt the assignments to the patient's development and wishes for rehabilitation. The people near the patient play an offensive role and can thus give their input on requirements both in terms of longer and shorter perspectives for hardware and software. Outlined requirements could be an essential part of the future implementation of a testbed for various forms of stroke rehabilitation. The planned future testbed should evaluate different techniques for motoric, cognitive and speech rehabilitation. This study has a focus on motoric stroke rehabilitation and how this might be supported by game-based learning initiatives.

1.1 Problem

Age related disabilities and their related issues make the idea of independent living difficult. In Sweden, percentage chronic diseases is considerably high in older adults and they tend to have two or more chronic diseases by the age of 77 (Marengoni et al., 2009). Stroke is also an age related chronic disease that is common in elderly population (Kamouchi, 2019). In sparsely populated areas like the Mid Sweden region there is a need for distributed and technology enhanced solutions to support the idea of independent living.

1.2 Research question

The important main question to answer in the study was: How might a game-based approach to motoric stroke rehabilitation support the idea of independent living?

2. Extended Background

Stroke rehabilitation can be divided into the three main categories of: cognitive rehabilitation, speech rehabilitation and motoric stroke rehabilitation (Ahmad, Mozelius & Ahlin, 2019). This study had a main focus on motoric stroke rehabilitation, and how motoric stroke might be reinforced by game-based learning.

2.1 Motoric impairment after stroke

Motoric impairment is the most common and widely known disability caused by stroke and approximately 80% of stroke survivors experience lack of muscle control in one side of the body that usually affect the left or right side of arm, leg and face (Langhorne et al., 2009). Consequently, most of the patients experience physical disabilities that lead to limit their daily routine activities such as ability to continue their professional work and personal care (Palmcrantz et al., 2017). Another crucial aspect of this impairment is compromised and limited social life of the patient (Langhorne et al., 2009). Due to reduced and limited mobility, a patient feels isolation and his ability to interact with other people decreased drastically, which create problems not only for the patient but also for the relatives and friends of the patient (Ahmad et al., 2019). Due to some other age related impairments, the elderly population suffers even more severely and they tend to lose real pleasure of life that eventually leads to depression (Broeren et al., 2008). Therefore, motoric impairment have some deep impacts on patient's overall life.

2.2 Motoric stroke rehabilitation

Since most of the patients suffer from motor impairment, motoric rehabilitation after stroke is very important for stroke survivors (Langhorne et al., 2009). Patients' capability to live independently heavily depends on the rehabilitation of the motor function especially the movement of upper limb function (Stinear & Byblow, 2014). Several studies recommend that the motoric rehabilitation process should start as early as possible and there should be continuous and long-term recovery plan for the patient (Palmcrantz et al., 2017, Ahmad et al., 2019).

Physiotherapy and some controlled exercises are recommended in most of the interventions for motor impairments and the evidence for usefulness of physical therapy is constantly growing (Veerbeek et al., 2014). In order to get the best results, physical exercises and training should be customized, task oriented, intense and in high dosage (Palmcrantz et al., 2017). Therefore, the role of occupational therapists and physiotherapists is very important in the motor recovery (Langhorne et al., 2009).

2.3 Game-based learning for older adults and stroke rehabilitation

In the 21st century there has been a rich production of digital games with a wide variety of what Juul (2010) has coined as 'casual games'. His two basic categories for casual games are: 1) games with mimetic interfaces and 2) downloadable casual games. A casual game with a mimetic interface often involves physical activity where the player mimics the activity shown on the screen. Examples of a gaming with a mimetic interface are to play tennis on a Wii platform or playing Guitar Hero. These kind of games can be seen as casual since the average person can look at the game and quickly understand the game idea. Important aspects for stroke patients since the motoric rehabilitation is based on physical activities, and that stroke patients' ability to learn complicated gameplay is limited.

As highlighted by Juul (2010) digital gaming is a phenomenon where the age group has extended, and the study by Charlier, Remmele and Whitton (2012) states that "With an aging population worldwide, the potential of games for use by adult learners, and in particular for older adults, is one that has been underexplored and one that will become of increasing interest in years to come." However, despite the increased gaming older adults may require longer periods of learning for interface devices with small buttons or small text. Which is particularly difficult for persons with a mobility, or a visual impairment. (Charlier, Remmele & Whitton (2012)

Exergames for the Nintendo Wii platform were used to improve balance and mobility for post-stroke patients, but the adaptation of interactive video consoles requires a careful pre-evaluation of the games (Deutch et al., 2011). Another approach is to develop serious games in the rehabilitation area, with the aim of a more properly design for the special learning needs in specific target groups. Finally, an interesting concept for post-stroke rehabilitation could be to use task-specific interactive game-based virtual reality systems (Shin, Ryu & Jang, 2014).

3. Method

The main research strategy in this study was a Design Science approach inspired by the process described by Johannesson and Perjons (2014). The five steps in their process are 1) explicate the problem, 2) define artefact requirements, 3) design and develop the artefact, 4) demonstrate the artefact and 5) evaluate the artefact. Many design science studies do not include all the five steps. This study had the aim of defining requirements for a game-based approach to motoric stroke rehabilitation. This was conducted as a Requirement-Focused Design Science project.

In Requirement-Focused Design Science Research, the artefact design should be outlined, but the study do not necessarily involve, implementation, demonstration or evaluation of the artefact. (Johannesson & Perjons, 2014). This study tried to define the requirements in a combination of a literature study, and by interviews with selected domain experts as pointed out by Weiringa (2014) expert opinions can be useful in the strive to get rid of bad design ideas early in a design science process. Furthermore, experts negative opinions can often more useful than experts' positive opinions in the improvement of an artifact's design (Wieringa, 2014). The nine experts chosen for this study can be found below in Table 1.

Table 1. Selected experts with professional roles and years of experience of Stroke rehabilitation

Informant	Professional role	Years of experience
Informant 1	Speech therapist #1	25
Informant 2	The region's medically responsible doctor	25
Informant 3	Therapist #1	5
Informant 4	Physiotherapist #1	8
Informant 5	Physiotherapist #2	3
Informant 6	Chairman of the local stroke patient organisation	3
Informant 7	Speech therapist #2	4
Informant 8	CEO for a small company working with game-based stroke rehabilitation	25
Informant 9	Hardware and software specialist at a big multinational company	9

Informants 3 to 5 work together in the local mobile stroke rehab team that is located at the region's main hospital. All in all, this mobile team includes one manager and four co-workers, adding one more therapist. This team is responsible for the patients' rehabilitation after the initial clinical care, when patients are in their home environment. The mobile stroke team also has contacts with Informant 2 and Informant 6 on a regular basis. Informant 8, and Informant 9 both work for companies with earlier involvement in projects with game-based stroke rehabilitation.

3.1 Data collection

Data were collected from semi-structured interviews with the nine informants that are listed above in Table 1. They all have important roles and can in various aspects be classified as experts on technology enhanced stroke rehabilitation. Informants have been selected in a purposive sampling where the involved researchers have relied on their own judgment in the selection. To carefully choose informants with expertise knowledge is a way to live up to the design science idea of expert opinions (Wieringa, 2014).

Requirements in this study data have been mainly been defined from data gathered by the semi-structured interviews, but also partly by a literature study. Interviews were based on a common question schedule but

with adaptations for each specific interview. The common question schedule included themes such as general stroke rehabilitation, specific stroke rehabilitation, game-based stroke rehabilitation and informants perceptions of technology enhanced stroke rehabilitation.

3.2 Data Analysis

Data were analysed inductively in a thematic analysis, to find patterns and themes that are essential to answer the research question. An analysis that mainly was based on audio recorded interviews and the transcribed recordings, but partly on written notes since some informants did not feel comfortable with recorded interviews. Firstly, each researcher conducted their own individual analysis of the interviews. Secondly the individual analyses were followed up by a joint analysis and discussions on which findings and themes that are the most important. Individual analyses were carried out stepwise with: meaning units, condensation, code, category, and themes. (Elo and Kyngäs, 2008, Bengtsson, 2016, Erlingsson and Brysiewicz, 2017). Finally, the most important findings to answer the research question were grouped into the three categories that are presented in the following section.

4. Findings and discussions

The interviewed experts have generously shared their knowledge, and also explained how today's stroke rehabilitation is divided into speech rehabilitation, cognitive rehabilitation, and motoric rehabilitation. To use games looks like a promising vitalisation of all these three branches, but the thematic analysis has a main focus on motoric stroke rehabilitation.

4.1 Hardware requirements

All the informants highlighted that the technology-enhanced systems requirements are different for different kind of stroke patients where degree of damage after stroke, age, overall health, social status and previous experiences of use of technology-enhanced systems plays an important role to determine the hardware requirements for patients (Informant 1-9). Informant 1 mentioned that the capability of using TES depends on how much patient's brain is affected by stroke. The use of smartphone or tablet where different application can be installed and used is recommended for the seriously infected Patients (Informant 1). Informant 9 also supported the same idea. The hardware such as mobile, tablet or a desktop computer should be able to install different kind of applications (Informant 9).

Since motor impairment reduces upper limb movement, eye-tracking navigation technologies can be useful for the patients (Informant 2). Informant 9 suggested voice recognition technology for stroke patients with reduced mobility. For example, if the patient just ask his desktop computer to start the rehabilitation application, it should just start without any physical input (Informant 9). Sensor technology can also be helpful for the navigation of TES (Informant 8, 9). For example, if a patient just wave his hand in front of the device, the device should respond (Informant 9).

The e-Health solutions should be interesting and joyful (Informant 1, 2). While designing these e-Health services or solution, it must be considered that patients with some serious brain and physical damage will be use those services (Informant 2). Informant 2 emphasized heavily on the importance of joyfulness and usefulness of e-Health services. The patients should feel a sense of happiness while doing some exercises with the help of TES and should feel the perceived benefits of those exercises (Informant 2). Both Informants from technical background suggested motion sensors or deep cameras combined with a screen with inbuilt software in home environment where a patient can play interactive games (Informant 8, 9).

In the rural areas of Mid Sweden region, availability of ICT infrastructure such as internet access is also a matter of concern (Informant 2-5). Informant 3 and 4 suggested that the hardware should be able to connect via mobile phone internet so that it can be used in the remote areas where accessibility of broadband and other type of wired internet is compromised (Informant 3, 4).

4.2 Software requirements

The brought up software requirements are here structured according to the stakeholders: (1) the caregiver, (2) the patient, and (3) the people close to the patient. Although this structure is it of importance to highlight that

current knowledge and research on stroke rehabilitation and the brain should be in focus for the requirements. He declared a difference between general aspects of rehabilitation and rehabilitation based on newly found insights on how a damaged brain function to some degrees repairs itself.

The requirements for the caregivers are several. One such is that they should be able to provide assignments on an individual basis, focusing on the wished development from the patient (Informant 2, 5, 6, and 7). Added to this are that the assignments need to be based on the caregivers' professional skills and safe to conduct. One example is given by Informant 7, who describes that the physiotherapist can use both video and images for physiotherapist assignments where the angle for a specific movement can be given. In alignment with this requirement is that the caregiver should have the possibility to produce explanatory assignments, adding an instructing perspective on the requirement. Informant 7 uses this in the initial part of the rehabilitation, especially when it comes to problem swallowing correctly. The caregiver also needs to get access to the patient's information, such as the number of conducted repetitions as well as time spent (Informant 2, 5, 6, and 7).

The patients' requirements on the software are based on their conditions and wishes for rehabilitation (Informant 2, 6, and 7). There should be possibilities to adjust the software and relate it to their background and current life situation. One example is given by Informant 7; highlighting the need for speech exercises related to older adults and their habits. Therefore, the software needs to include a flora of assignments, which can be mixed independently of one another and that the patients can perform them independently of others or minimal efforts from nearby people. Both informant 4 and 7 highlights the requirement that the software should be based on the patient's native language to be understandable.

Informant 4, 5, and 7 argue for the persons near the patient and their importance for stroke rehabilitation. They focus on the software's ability to involve them or let them help the patient with various activities related to the rehabilitation. One such is that there should be functionality for them to access the assignments or the conducted assignments to support the rehabilitation. Informant 7 describes this as both supporting the patient and the caregiver. Given example is when the caregiver and patient have a distance-call and the patient needs supportive help to be part of the conversation.

4.3 Game-based stroke rehabilitation

The most positive finding in the study was that all informants embraced the idea of game-based stroke rehabilitation. Digital as well as analogue games are already used in both speech therapy (Informant 1) and in cognitive rehabilitation (Informant 3) of stroke patients. Using games in motoric rehabilitation of stroke patients seems to be less frequent, but both Informant 5 and Informant 6 find the idea interesting. There exists a wide variety of exergames and gym exercises that have good probabilities for adaptation to stroke rehabilitation. Games' identified strong motivating effect can be a valuable contribution (Informant 2), and all activities do not necessarily have to be rule-based gaming, more free and playful activities like virtual dancing would be highly appreciated. Activities with music and dancing are also what many members in the local stroke patient organisation would see in the future (Informant 6).

What many informants emphasised was the large variation in both rehabilitation needs, and in stroke patients' digital skills (Informant 1; Informant 5; Informant 6). Considering this, fundamental the idea must be to provide a smorgasboard with different casual games, both digital and analogue. For some patients, it would be joyful to play virtual golf, for other the choice might be analogue or digital labyrinth games (Informant 3; Informant 5). It is tempting to invest in sophisticated gaming consoles with motion detection and high-end audio, but stroke patients' cognitive abilities might hamper patients' possibilities to interact with complex game environments. This must, as all other stroke rehabilitation be individually adapted.

As highlighted by Informant 1, there are no games that fit all stroke patients. There are huge variations in cognitive and physical abilities among stroke patients. As an example, the full field of view is sometimes blurred which can make the gaming problematic. New complex graphical user interfaces can also be troublesome to learn and to use. Informant 6 brought up the idea that stroke patients often have to relearn, and when many daily skills should be relearned, it can be hard to also learn how to navigate in unknown digital interfaces (Informant 3, Informant 6). Hard-core games with complex gameplay and long gaming sessions should be avoided for a target group with limited energy. The idea of using casual games looks worth further

testing both for exergames such as virtual table-tennis on large screens, and downloadable mobile games to play at any time in patients' home.

The popular concept of Bring Your Own Device (BYOD) seems promising for patients with a reduced ability for learning and relearning (Informant 1, 4, and 5). The fundamental idea behind BYOD is that learners should use their own devices, and not be limited to the use of pre-configured devices. This BYOD concept has been successfully tested in various educational and industrial settings. BYOD is less tested in e-Health contexts, but as pointed out by Brooks (2014) this can be a valuable contribution to traditional healthcare and rehabilitation.

5. Conclusion

Considering the wide variety of professional roles among the selected informants, their consensus on the potential for game-based rehabilitation must be seen as a both positive and surprising finding. Furthermore, all informant took their time and gave valuable and detailed answers that will be useful for the implementation of a stroke rehabilitation testbed. Findings for the three categories can be summarised as in the following paragraph.

Firstly for the hardware category, the technology-enhanced systems requirements must be different for different types of stroke patients and personalised. The degree of stroke damage, age, overall health, social status and ICT proficiency should always be considered. Since stroke patients often lack energy for relearning the idea of BYOD seems promising, and to use existing and familiar devices to a high degree. Secondly for the software category, there is the same need for personalisation, but besides the variations depending on patients' conditions their personal preferences must be considered. Furthermore, software requirements should not only involve patients' requirements, but also consider caregivers and patients' relatives. Thirdly, the requirements for the category of Game-based stroke rehabilitation should have a focus on casual games, where both games with mimetic interfaces and downloadable mobile games look promising. And, of course with the same personalisation as for the earlier categories, not all patients' want to play a game with elk hunting, and neither do all patients' have the physical ability to play virtual tennis.

The requirements of individual adaptation that appears in all three categories is an important key factor if the game-based stroke rehabilitation should be able to support the idea of independent living. Finally, the suggestion to involve software for joyful virtual dancing is interesting and as Huizinga (2016, p. 164) wrote about dance: "... it is always at all periods and with all peoples' pure play, the purest and most perfect form of play that exists".

6. Future work

The requirements outlined in this study have a potential to be a valuable contribution to the planned future implementation of a testbed for stroke rehabilitation. In this testbed the presented GBL ideas should be evaluated in detail. It would also be interesting to further investigate the potential for involving game-based speech rehabilitation and how to involve GBL in cognitive rehabilitation of stroke patients.

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