

Determining Testbed Requirements for Technology Enhanced Speech Rehabilitation after Stroke - the Informed Co-workers' View Point

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Abstract—This paper analyses and discusses the identified requirements for technology enhanced systems for speech rehabilitation after a stroke. To stroke patients, a speech injury can be devastating, impacting their abilities to speak, listen, read, and write. Therefore, speech therapy is recommended as early as possible. To address the challenge with a growing percentage of older adults, therapy should include a variety of Technology Enhanced Systems (TES) to support the idea of independent living. These systems must be adapted to the patients' needs and speech therapy requirements. Based on a design science approach, requirements were determined from an analysis of ten semi-structured interviews with knowledgeable informants. Findings indicate several important requirements, such as: TES should be motivating, joyful, individualised and built on patients' needs and on speech therapists' professional knowledge. Furthermore, TES services must be user-friendly and provide training in each patient's mother tongue. Added to these requirements are ease of including close relatives as supporting persons, as well as accessibility through portable devices.

Keywords—*e-health; HCI; stroke rehabilitation; independent living; speech therapy; requirements*

I. INTRODUCTION

Stroke is one of the most common and serious diseases across the globe; it can cause death or a variety of disabilities [1]. Stroke is caused by an interruption of blood flow to the brain that affects neuronal cells, which leads to severe impairments in brain function [2]. Generally, a stroke patient's disability can be classified into motor, speech and cognitive injuries [3]. This paper focuses on speech injuries which impact both speech and language function, which can reduce drastically a person's abilities to speak, listen, read and write [2]. Because of that, quality of life is severely compromised and patients' overall social interactions decrease. These changes have long-lasting impacts on patients' personal and professional lives. Therefore, various types of speech therapy are recommended as early as possible after stroke [3]. A large number of traditional treatments are available for speech recovery, but providing access to treatments to all stroke patients is challenging because of the high cost for human resources and day-to-day

operational requirements needed for these intervention types. For speech and language retrieval, high-intensity and long-term therapy is needed and current medical interventions cannot provide those services due to limited resources [15].

In the last two decades, Technology Enhanced Systems (TES) have been recognized as highly useful for several treatment types that involve multiple rehabilitation therapies [3]. Indeed, several therapy systems have been successfully developed using modern technologies [4]-[6]. Recent studies highlight that different types of TES can be useful for speech and language rehabilitation, combining various categories of technologies, such as: tele rehabilitation based on audio and videoconferencing [2][15], internet-based therapy [19], serious game-based therapy [21] and Virtual Reality based therapy [6].

After a stroke, however, due to brain function impairments, a patient's ability to understand and learn new things is decreased drastically, which creates challenges for patients in adopting and using TES [3]. Therefore, users' requirements need to be considered during speech and language rehabilitation and a user-centered design approach may be most effective, so that the more difficult learning process can be easier after a stroke [7]-[10]. Some studies highlighted the importance of user-friendliness and usability issues for TES [9][19]. However, a Requirement-Focused Design Science approach, where relevant stockholders such as medical caregivers and people with technical backgrounds are involved, seems to be rarely used. The requirements to develop TES for speech and language rehabilitation should additionally be considered from a clinician's perspective [19].

This study focused on the viewpoint of co-workers working with stroke patients. The co-workers were all experienced in rehabilitation procedures and patients' therapy. This study concentrated on these informed co-workers' viewpoints to determine which requirements are essential for the user-friendliness and usability of TES, distinguishing between functional and non-functional requirements. Therefore, the main research question was:

What are the testbed requirements of technology-enhanced systems for speech rehabilitation after stroke, based on informed co-workers' viewpoints?

Presented in Section 2 is an extended background, declaring previous research on, e.g., speech rehabilitation. Section 3 describes the study's research method, which is Design Science. Declared in Section 4 are the findings from the study. Section 5 includes the discussion and presented in Section 6 is the conclusion.

II. EXTENDED BACKGROUND

Presented in the extended background is previous research on speech rehabilitation for stroke patients and requirements for TES in speech rehabilitation.

A. Speech rehabilitation for stroke patients

Stroke rehabilitation is a challenging task for both patients and healthcare providers, as it requires high motivation and hard work from the patients, and extensive resources from the stroke rehabilitation staff [5]. Difficulties related to speech and language are classified as a condition called aphasia. Aphasia is one of the common stroke impairments where a patient's cognitive performance may not be decreased, but the ability to speak, read and/or write is affected to some degree [2]. Almost one third of patients suffer from aphasia after stroke [2][11]. After a stroke, most speech and language impairments recover during the first few weeks but the rest of the recovery may take several years; t speech and language therapy has been seen to be an effective intervention to enhance the recovery process [12].

Several studies confirmed that the quality of life of people with chronic aphasia is severely affected because of their emotional suffering, social limitations, communication disorders, and their overall health condition [13]-[15]. Most aphasia patients also suffer from anomia. During anomia, a person's capacity to find appropriate words is reduced, which creates major problems in a patient's daily life [2]. Because of their speech and language disability, stroke patients can no longer express their emotions, opinions, thoughts, personality and knowledge, and that lack of expression leads to deep frustration [16]. Another impact of speech inability is increased uncertainty and fear. The patients become uncertain about what is said and what is understood, leading to doubts about what was planned in the past and a continuous fear of future unpleasant situations. Consequently, this devastating disability impacts the people living around the patient such as relatives and friends [15].

An improvement in speech and language abilities is an overall goal for aphasia rehabilitation and Speech and Language Therapy (SLT) plays an important and effective role in reaching this goal [15]. Several studies highlight the benefits of SLT such as improvement in expression, reading and writing [17]. Moreover, some evidence has shown that highly intensive, highly dosed, and long-term therapy have better results as compared to low intensity, low dosed and

short-term therapy [15]. To increase accessibility and decrease the cost of such therapy, the requirements for TES to be an affective supplement in speech therapy is of special interest.

B. Requirements for TES in speech rehabilitation

Here, the functionality for TES in speech rehabilitation is divided into functional requirements and non-functional. The functional requirements include specific elements of TES that support speech therapy, such as word training. Non-functional requirements refer to general elements of TES, such as a specific color scheme.

Consideration of non-functional requirements for rehabilitation includes that it should be joyful to conduct and experience, especially since stroke patients mainly suffer from fatigue and therefore need extra encouragement to train [18]. The encouragement can be based on game-like aspects, with follow-up situations where extra training results in various gratifications. As such, functionality of follow-ups is of interest, both from a patient's and a speech therapist's perspective [18][19]. Rybarczyk et al. [18] state that other general requirements are that the TES should be based on therapeutic material and be designed according to different levels of language complexity.

The functional requirements for speech rehabilitation must be personalised based on the patient's condition and intention [19][20]. Simic et al. [19] describe the need for a user-centered design based on the patient's individual set of conditions, emphasising that most TES for speech training assumes some base level of communication. Unfortunately, this base level varies from patient to patient and may frequently be lower than TES designers assume, which results in patients who are unable to access the training at all. Patient's intention refers to their internal desires for successful rehabilitation, where stroke patients' motivation for recovery varies. Simic et al. [19] point out that a patient's intention might interfere with that of the speech therapist and could affect the training based on TES.

In personalising the TES to a patient's condition and intention, several aspects of speech therapy must be included as functional elements. For example, object identification, which includes *simple* followed by *complex* order comprehension, is described as one part of the functionality [18]. Simple order comprehension is based on the construction of a sentence including name-verb-direct complement. One such example is: "Put the knife close to the plate." A complex sentence adds a coordinate or a subordinate sentence, e.g., "Put the knife close to the plate and the fork to the left of the knife." Within the training for order comprehension, Rybarczyk et al. [21] adds functional elements, emphasising that the TES should include an ability to train writing exercises and text, word selections, and specific questions. The order of the writing exercises, or any exercise, should be easy for the speech therapist to personalise for their patients, offering various ways for developing the training based on a patient's condition and

intent. Besides requirements mentioned earlier, the training must be based on the patient's mother tongue which means TES should be available in many languages; currently several training programs only are available in one language, e.g., English [20][21].

Identified non-functional requirements include adaptable user control interfaces, potential of using a tablet, user-friendly graphical layout, and tangible interfaces. The user control interface must be adaptable to multiple levels of patients' motor disabilities and there should be the possibility to use a tablet for training [22]. The ability to use a tablet allows more than one person to easily see and use the interface, because relatives and other members of a support network can help the stroke patient learn to use the tablet. Another helpful aspect of using a tablet is that during training this smaller device offers significant support. For example, it can support discussions between a person and a patient where pointing at a picture on a tablet is easy.

Rybarczyk et al. [18] and Rybarczyk et al. [21] stress several non-functional requirements, including the graphical layout. In [18], ease of use of a graphical layout, including oral and written instructions, for an ordinary speech training software is considered to be essential, to support patients with multiple levels of disability who may struggle to learn to use the software and/or who need the assistance of a relative or other person. They focus on potential tangible interfaces, e.g., allowing a user to touch and move objects while training ordering of words. Still, the starting point for any user interface should be a healthy person's ability to use a software program, e.g., hierarchical menus and an ordinary login based on, e.g., a mail address and a password decided by the user. Rybarczyk et al. [21] describes the context of VR as a training environment, which could support individualising the interface by allowing the stroke patient to adjust the control sensitivity with, e.g., a joystick.

III. METHOD

This study was carried out with a Design Science approach inspired by a process [23]. The five steps in this process are 1) to explicate the problem, 2) to define requirements for an artefact, 3) to design and develop an artefact, 4) to demonstrate the artefact and finally 5) to evaluate an artefact. Many design science studies, however, carry out only a subset of all five steps. For example, with the aim of defining requirements for technology enhanced speech rehabilitation, Their study was designed with the focus of a Requirement-Focused Design Science project. In Requirement-Focused Design Science Research, artefact design (step 3) is outlined, but does not involve implementation, demonstration or evaluation of the artefact (steps 4 and 5) [23]. The current study, based on an existing problem, tried to similarly define requirements based on a combination of literature review and interaction with selected experts.

As highlighted by [24], expert opinions can be useful to eliminate bad design ideas early in the design science process. Experts' negative opinions can often be more useful than experts' positive opinions to improve the design of an artefact.

A. Data collection

Data have been collected from the ten informants that are listed in TABLE I.

TABLE I. SELECTED INFORMANTS

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
Informant 10	Head of Stroke Team	15

Informants #3 to #5 and #10 work in the mobile stroke rehabilitation team located at the region's main hospital. The entire mobile team includes one manager and five co-workers. The team is responsible for rehabilitation after initial clinical care when patients have been relocated to their homes. The mobile stroke team also has regular contact with Informants #2 and #6. Informants #8 and #9 are independent of any clinical stroke organisation.

All informants have different important roles in contemporary stroke rehabilitation. Each was selected in a combination of purposive sampling and snowball sampling. Purposive sampling is a technique where the involved researchers rely on their own judgment when choosing informants. Snowball sampling means that researchers find new informants that are recommended by earlier informants. All informants have expert expertise in the investigated area and were carefully selected to satisfy the design science idea of using expert opinions [24].

To define requirements in this study, data have been gathered mainly by semi-structured interviews and partly by a literature review. All interviews were carried out with a common instrument with a set of basic questions that allowed adaptation to the various interviews, see appendix 1. The common question schedule included themes such as general stroke rehabilitation, speech rehabilitation, informants' understanding of the use of TES, and their views on the potential for TES' use in speech rehabilitation of stroke patients. The interviews were all conducted in person with informants; at least one researcher attended. The interviews lasted between 45 to 90 minutes.

The context for stroke patients was mainly the Jämtland/Härjedalen region, a part of Sweden that covers spread-out rural areas and few inhabitants. Many stroke patients live in rural areas, meaning travel requirements affect the mobile stroke team. The team must limit their area for home rehabilitation visits to 70 kilometres from the hospital located in the region's city. Therefore, the patients living further away must stay at a nursing home, located close to the region's hospital, for shorter time periods (approx. two weeks) during their rehabilitation. IN addition, this spread of rural areas affects the use of TES, because rural areas may have limited bandwidth and spots without Internet access (Informants #3 - 5).

B. Data analysis

An inductive thematic analysis was conducted to find patterns and themes useful for answering the research question using interpretations rather than measurements. The analysis was based on audio recorded interviews and the transcribed recordings. Each researcher conducted an individual analysis followed by group discussions to compare analyses, resolve questions and inconsistencies, and determine which findings, and their relationships, to include. The individual analyses followed the following steps, described below: identifying meaning units, condensing meaning units to fit the study, coding units to identify requirements, categorising identified requirements, and arranging categories within themes [25]-[27]. Meaning units are expressions from the informants in favour of speech rehabilitation. After identifying interesting meaning units, each researcher wrote them down for further work. After identifying meaning units, each researcher synthesised them by creating excerpts of the core ideas that could potentially address the research question of the study. The

coding identified individual requirements for speech rehabilitation, such as using patients' native languages as a foundation. The individual requirements were then aggregated into categories, based on the various speech disabilities resulting from stroke. The categories were arranged within the previously presented functional and non-functional themes. The arrangements of categories were based on various speech disabilities related to stroke and the perspective of functional or non-functional requirements. After each researcher completed the individual analysis, the group met to compare meaning units, excerpts, coding, categories, and themes. Final decisions about categories and themes were discussed and agreed upon by all researchers. Relevant findings from the analyses are presented in the next section.

IV. FINDINGS

After a stroke, due to speech and cognitive impairments, a person's ability to understand, express and communicate is decreased; therefore, the TES should be adjusted according to the patient's medical condition (informant 1, 2, 7). Informant 1 explained that described that there are many mobile phone and tablet-based applications that are recommended for speech rehabilitation; however, the success of these interventions heavily depends on the patient's medical condition, such as how much of the brain function is impaired after stroke. Informant 1, 2 emphasised that the TES should be easy to use and patients should feel a sense of joyfulness when using the TES. All but three informants, including the two speech therapists, highlighted the importance of user-centred design for the TES (Informant 1-5, 7, 9). Generally, non-medical professionals develop most of the TES for speech rehabilitation; therefore, they do not understand the needs and limitations of stroke patients. Informant 7 argued that TES should be designed in cooperation with speech therapists and they should be involved throughout the process.

Informants 1 and 7 express the following variations on speech problems for the stroke patient: dysphagia (problems with swallowing), aphasia (see earlier description), and dysarthria (reduced mobility in the muscles used in speech). Initial speech problems are mainly related to dysphagia since the patient is unable to consciously initiate a swallow. Informant 7 shows a TES that supports training to swallow, with English narration. When using the TES, Informant 7 must off the sound and talk to the patient in Swedish.

Patients with severe aphasia may suffer from complete loss of speech function; therefore, pictures and video-based applications can be helpful (Informant 1, 7). For less damaged patients, using a TES to record and replay speech is recommended as a process that can improve speech function and pronunciation.

An interesting finding is that several informants emphasise the importance of considering the patient's vision (Informant 1). Many TES have been developed for persons

with a full field of view. For many stroke patients, the full field of view is blurred, creating problems while using many TES. Unknown and complex graphical user interfaces can also be troublesome to learn and accept. As mentioned by Informant 6, stroke patients have to relearn many everyday tasks which is a cognitive overload that can make it difficult to also learn how to navigate new user interfaces (Informant 3, 6).

The speech therapists emphasised the need for communication tools based on speech problems after a stroke (Informant 1, 7). Communication difficulties can be reduced in various ways; for example, by using images or other alternative communication strategies. The lack of TES for easy communication is evident since the demonstrated ones are adapted from technologies initially developed for children in elementary school. Informant 7 explained that most of the currently available TES are initially developed for school-going children and then speech therapists use them after making adjustments. The content is not adjusted for situations in adult lives; for example, content does not include training for describing daily routines, such as having a cup of coffee or going to the grocery store, with adjustable degrees of difficulty. Patients' communication needs are therefore unsupported. Hence, TES that supports communication training should be specifically designed for stroke patients.

To use TES, significant education and training is needed (Informant 1-5, 7), not only for the patients but the clinical staff as well (Informant 7). To set up proper training, a wide range of multimedia functions and content should be available to adjust to the needs of each patient. Thusly, the speech therapists need to understand the TES and its functions to adjust it for each patient. Informant 7 explains the need for understanding by describing necessary technical tasks; for example, bringing together appropriate interactive pictures and video-clips to demonstrate TES information and training material. One example of lack of education and training was that the staff at a stroke rehabilitation centre was not very comfortable with the use of technology for distance interaction, such as Skype or Zoom (Informant 2, 7, 10). Speech therapists needed, for example, to show a video clip while, at the same time, they instructed the patient or relative. Hence speech therapists need interactive guidance to support the stroke patients' use of Skype. Patients' personal integrity is also of importance during training and education via Skype (Informant 2-5). People do not often feel comfortable being monitored or recorded via video cameras and therefore this type of monitoring technology should not be used frequently (Informant 2). Importance of proper education and training is even more vital for stroke patients, who often are older adults. Older adults with limited previous e-technology knowledge or experience tend to have more difficulties in learning to use TES than younger adults with knowledge or experience (Informant 1-5, 7). The problem with adjustment to TES arises for stroke patients doing their rehabilitation at

the nursing home, since the staff working there are seldom interested in information technology and thus do not support patients in learning to use the TES (Informant 7).

Another load on speech therapists who work with stroke patients is the lack of speech therapists working at the centre for accessibility aid. When prescribing a tablet and software to a stroke patient, the tools are rarely correctly adjusted for the patient. Therefore, the prescribing speech therapist needs to configure both tablet and software by themselves. Related to this struggle is the concept of Bring Your Own Device (BYOD). Three informants (informant 1, 3, 6) bring up the concept in their interview answers. BYOD means that users are not limited to use pre-configured devices, but that they also can use their own devices. BYOD must not be restricted to mobile phones and smartphones and should also include tablets, laptops and desktop computers. However, the two devices that were brought up were mobile phones and tablets. Informant 1 uses applications that can be run on simple mobile phones, while Informant 4 uses applications that need a smartphone with support for email and web login. Their main argument is that a familiar navigation system is extra valuable in a situation where the patients' cognitive ability to learn and relearn is reduced. If BYOD acronym is extended to Bring Your Own Technology (BYOT), a term coined by Intel [28], technology-enhanced stroke rehabilitation must include patients' Internet access, which could be limited in the region's rural areas.

The findings in this study can be summarised as:

- TES services should be easy to use and bring patients a sense of joyfulness
- The development of TES services should involve both users and medical professionals, and strive for an individualised design
- Speech rehabilitation services should be accessible in patients' mother tongues and not only in English
- A variety of TES services should be provided, including solutions tailor-made for older adults, considering both content and graphical design
- Stroke patients must constantly relearn, and their ability to learn new interfaces is limited
- The concept of Bring Your Own Technology seems promising, with the idea of patients using devices that already are familiar

V. DISCUSSION

Several functional requirements, including adaptability to each individual stroke patient as an overall requirement, for TES supporting speech rehabilitation is described in the literature [18]-[21]. This overall requirement is emphasised in the empirical material, which describes speech therapists doing their best to adjust to individual stroke patients by using TES that is not initially designed for the rehabilitation situation. Content of the TES, especially when perceived as

irrelevant to patients' lives, could diminish the motivation of the patients, who thereby lose interest in continually developing their communication skills. One possible reason for the lack of adaptability could be that speech therapists rarely are involved in the development of TES for speech rehabilitation and the designers therefore lack understanding of stroke patients' various conditions and needs. Some conditions are understood in clinical terms, such as the categorisation of various conditions within anomia [2] or dysarthria. Despite the existence of clinical identifications and categorisations of conditions, commonly known by speech therapists, TES developers seemingly do not include them in TES design. In addition, TES that include narratives in the patients' mother tongue (e.g., Swedish) are scarce, resulting in frustration both for the speech therapist and the patient. For the speech therapist, this lack of language support results in increased workload; for the stroke patient it serves as a reminder of the new limitations in their life [13]-[15].

Follow-up with patients by the speech therapist is a somewhat delicate assignment nowadays. Data on follow-ups should be available to the therapist in a way that allows efficiency to see which assignments are conducted, but also guarantees privacy for the stroke patient. The patients have the right to declare their data as private, limiting access by the speech therapist. These rights are important, but therapists, on the other hand, lose control of a patients' speech development process, needing to believe in the patients' descriptions of their progress. Here, the relatives can play an important role, by being a bridge between the patient and the speech therapist. By adding possibilities for relatives, or close friends, to be part of the rehabilitation using TES, the follow-up and the patient's motivation to continue the training could be improved. These issues highlight the importance of trust between the therapist and the patient, in addition to the patient's motivation to develop his/her speech skills.

Non-functional requirements, focusing on the graphical layout, are found in the literature [18][21]. They declare that the design of the TES should be interactive, entertaining, and easy to use. To set up proper communication or training, there should be a wide range of multimedia functions and content to adjust to the needs of each patient and the different goals of the rehabilitation. Examples of multimedia functions include interactive pictures and video-clips that a speech therapist can use to demonstrate the information and training instructions or material. The requirement should focus on providing variation in types of multimedia, allowing possibilities for adjustment.

Rarely mentioned in the literature, but emphasised in the empirical material, are specific requirements for training the use of the TES. The speech therapists and stroke patients need general training for both TES and hardware, such as tablets, offering more accessible paths for communication [22]. Just as few TES are designed for stroke rehabilitation, there are few possibilities for education in TES for stroke

rehabilitation. Training themselves and patients to use the TES becomes the responsibility of the speech therapist, and is impacted by the stroke patient's motivation for learning. One factor which could affect this motivation positively is the size of the region and the long distances: If patients learn to use TES quickly, its use could improve efficiency in the rehabilitation and decrease the time spent in nursing homes. Motivating the speech therapist to gain more knowledge about both software and hardware should be a result of strategic decisions made by the employer. When education is discussed in the literature, it is described as being conducted in both written and oral forms, lacking any training the form of video [18]. In addition, the lack of communication tools focusing on the stroke patient's daily life can cause additional difficulties for the speech therapist, which is rarely mentioned in the literature.

The BYOD concept is spreading to new contexts including hospitals. As in many other fields, the BYOD practice can be time-efficient and cost-effective for hospitals, but include challenges with standardisation and security. For distributed stroke rehabilitation in patients these issues seem less problematic. The authors' recommendation is to focus on usability and user-friendliness, which highlights the importance of BYOD, because stroke patients have reduced capacity to use and learn complex interfaces, requiring familiar and user-friendly navigation systems.

VI. CONCLUSION

Few available softwares for stroke patients are designed using the knowledge of the speech therapists. Shown here is that the design of the TES (Technology Enhanced Systems) should be interactive, joyful, and easy to use. To set-up proper communication or training, there should be a wide range of functions and content to adjust to the needs for each patient and the different goals of the rehabilitation. This requirement is based on the different goals with the rehabilitation, as well as the specific needs for the individual stroke patient. Example of a function is that of multimedia in which a speech therapist can use to demonstrate the information and training instructions or material. The multimedia function could include interactive pictures and video-clips. Another important requirement is that the software should be accessible for relatives or close friends to help whenever needed.

A. Future work

The applications used for speech therapy are developed with other user groups in mind. For example, applications are designed for students in elementary school, and therefore include material for children, such as pictures of kids' games and activities. Applications must be designed with material that is relevant for stroke patients. Another impediment is that the language in the software is often English, rather than the mother tongue of the stroke patients. Therefore, we propose further prototyping, development,

and testing of TES to enrich the foundation for speech therapy after a stroke. Finally, it is also important to involve stroke patients in the future work, to get their early and continuous feedback during the development of a software prototype.

REFERENCES

- [1] P. Langhorne, J. Bernhardt and G. Kwakkel, "Stroke rehabilitation", *The Lancet*, 377(9778), pp. 1693-1702, 2011.
- [2] M. Tousignant et al., "Satisfaction With In-Home Speech Telerehabilitation in Post-Stroke Aphasia: an Exploratory Analysis", *Journal of the International Society for Telemedicine and eHealth*, 6, pp. e11 (11-18), 2018.
- [3] A. Ahmad, P. Mozelius and K. Ahlin, "Testbed requirements for technology enhanced stroke rehabilitation to support independent living", in Editor (Ed.)^(Eds.): 'Book Testbed requirements for technology enhanced stroke rehabilitation to support independent living' (INSTICC Press, 2019, edn.), 2019.
- [4] H. Zhang , Z. Shen, J. Lin, Y. Chen, and Y. Miao, "Familiarity design in exercise games for elderly", *Int J Inf Technol*, 22, pp. 1 – 19, 2016.
- [5] T.P. Yamato, J.E. Pompeu, S.M. Pompeu and L. Hassett, "Virtual reality for stroke rehabilitation", *Physical therapy*, 96(10), pp. 1508 – 1513, 2016.
- [6] J. Broeren, A. et al., "Virtual rehabilitation after stroke", *Studies in health technology and informatics*, 136, pp. 77 2008
- [7] C. Pagliari, "Design and evaluation in eHealth: challenges and implications for an interdisciplinary field", *Journal of medical Internet research*, 9, (2), pp. e15, 2007.
- [8] R.E. Glasgow, "eHealth evaluation and dissemination research", *American journal of preventive medicine*, 32, (5), pp. S119-S126, 2007.
- [9] A.D.V. Dabbs et al., "User-centered design and interactive health technologies for patients", *Computers, informatics, nursing: CIN*, 27, (3), pp. 175, 2009.
- [10] L. Neuhauser, G.L. Kreps, K. Morrison, M. Athanasoulis, N.Kirienko and D. Van Brunt, "Using design science and artificial intelligence to improve health communication: ChronologyMD case example", *Patient education and counseling*, 92, (2), pp. 211-217, 2013.
- [11] J. Greener, P. Enderby and R. Whurr, "Speech and language therapy for aphasia following stroke", *Cochrane Database of Systematic Reviews*, (4), 1999.
- [12] A. Gerstenecker and R.M. Lazar, "Language recovery following stroke", *The Clinical Neuropsychologist*, pp. 1-20, 2019.
- [13] K. Hilari, R. Wiggins, P. Roy, S. Byng and S. Smith, "Predictors of health-related quality of life (HRQL) in people with chronic aphasia", *Aphasiology*, 17, (4), pp. 365-381, 2003.
- [14] K. Ross, and R. Wertz, "Quality of life with and without aphasia", *Aphasiology*, 17, (4), pp. 355-364, 2003.
- [15] H.P Øra, M. Kirmess, M.C. Brady, I.E Winsnes, S.M. Hansen and F. Becker, "Telerehabilitation for aphasia—protocol of a pragmatic, exploratory, pilot randomized controlled trial", *Trials*, 19, (1), pp. 208, 2018.
- [16] M.B Johansson, M. Carlsson and K. Sonnander, "Communication difficulties and the use of communication strategies: from the perspective of individuals with aphasia", *International journal of language & communication disorders*, 47, (2), pp. 144-155, 2012.
- [17] M.C. Brady, H. Kelly, J. Godwin, P. Enderby and P. Campbell, "Speech and language therapy for aphasia following stroke", *Cochrane database of systematic reviews*, (6), 2016.
- [18] Y. Rybarczyk and J. Fonseca, "Tangible interface for a rehabilitation of comprehension in aphasic patients", 2011.
- [19] T. Simic, C. Leonard, L. Laird, J. Cupit, F. Höbler and E. Rochon, "A usability study of internet-based therapy for naming deficits in aphasia", *American Journal of Speech-Language Pathology*, 25, (4), pp. 642-653, 2016.
- [20] P. Kesav, S. Vrinda, S. Sukumaran, P. Sarma and P.Sylaja, "Effectiveness of speech language therapy either alone or with add-on computer-based language therapy software (Malayalam version) for early post stroke aphasia: A feasibility study", *Journal of the neurological sciences*, 380, pp. 137-141, 2017.
- [21] Y. Rybarczyk, J. Fonseca and R. Martins, "Lisling 3D: a serious game for the treatment of portuguese aphasic patients", in Editor (Ed.)^(Eds.): 'Book Lisling 3D: a serious game for the treatment of portuguese aphasic patients' (edn.), 2013.
- [22] K. Mallet et al., "RecoverNow: A patient perspective on the delivery of mobile tablet-based stroke rehabilitation in the acute care setting", *International Journal of Stroke*, 14, (2), pp. 174-179, 2019.
- [23] P. Johannesson and E. Perjons, "An introduction to design science" (Springer, 2014), 2014.
- [24] R.J. Wieringa, "Design science methodology for information systems and software engineering" (Springer, 2014), 2014.
- [25] S. Elo and H. Kyngäs, "The qualitative content analysis process", *Journal of advanced nursing*, 62, (1), pp. 107-115, 2008.
- [26] M. Bengtsson, "How to plan and perform a qualitative study using content analysis", *NursingPlus Open*, 2, pp. 8-14, 2016.
- [27] C. Erlingsson and P. Brysiewicz, "A hands-on guide to doing content analysis", *African Journal of Emergency Medicine*, 2017, 7, (3), pp. 93-99, 2017.
- [28] A. Freeman, S.A. Becker and C. Hall, "2015 NMC Technology Outlook: Brazilian Universities", in Editor (Ed.)^(Eds.): 'Book 2015 NMC Technology Outlook: Brazilian Universities' (The New Media Consortium, edn.), 2015.

APPENDIX 1

A. First interviews

1. How do you currently work with Stroke Rehabilitation?
2. What different technology-supported solutions have you been in contact with when it comes to Stroke rehabilitation and to what extent have you used these? Pros and Cons?
3. What requirements do you think should be met for e-solutions at rehab clinics as well as in the patients' home environment?

4. How do you think that your patients have received technology-supported solutions? Any differences in age, gender or education?
5. Have you encountered any problems or conflicts regarding technology-supported solutions for Stroke rehabilitation, such as current ownership, use, support?
6. Do you want you to use more / have more knowledge about technology-supported readings for stroke rehabilitation?
7. To what extent do you have your workplace opportunity/budget to try new e-solutions?
8. What are your background/education and your relationship with this area?
9. Is there anything that you think I forgot to ask about?

B. Second interview with speech therapists

1. What is language reduction?
2. Can you explain the diagnosis of aphasia, dysarthria, verbal apraxia and dysphagia?
3. Can you explain the rehabilitation for aphasia, dysarthria, verbal apraxia and dysphagia?
4. Can you describe your functional requirements for an application for aphasia, dysarthria, verbal apraxia and dysphagia?
5. Can you describe your non-functional requirements for an application for aphasia, dysarthria, verbal apraxia and dysphagia?
6. Do you see any special requirements (general and for an application) in terms of speech rehabilitation for stroke patients in Region J / H?