

TECHNOLOGY-ENHANCED SPEECH AND LANGUAGE RE-LEARNING FOR STROKE PATIENTS- DEFINING REQUIREMENTS FOR A SOFTWARE APPLICATION DEVELOPMENT

Research paper

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Abstract

Speech and language relearning are challenging for stroke survivors as well as for medical caregivers. After a stroke, a patient's ability to read, write, speak, and listen is decreased to different degrees, which results in a compromised independent life and a decreased quality of life for the patient. Technology enhanced systems can play a vital role in this context. However, the available software are not specifically built for after the stroke patient's needs. This paper is therefore aimed to gather requirements for designing a tailor-made speech relearning software application for stroke survivors. A design science approach was adopted, where different stakeholders such as medical caregivers and information technology consultants were involved in the process. The well-informed and experienced participants in their fields highlighted some important requirements such as different types of interface for a patient than speech therapist with extra management functionality for speech therapists so that they can adjust the relearning exercises according to the patient's needs. Software requirements vary from patient to patient where the intensity of speech and language impairments, general medical condition of the patient, age, prior experience, and knowledge about the information of the patient and social setup of the patient plays an important role. Since stroke is most common in adults and adults learn differently than children, adult learning theory might help understand the patients' needs. Therefore, adult learning principles were involved in the requirement analysis process. The established requirements will be used for the development of speech and language relearning software.

Keywords: E-Health, Stroke rehabilitation, Speech relearning, Adult learning, Independent living, Requirements specification

1 Background and problem motivation

Stroke is one of the most common causes of death and different kinds of chronic disabilities in adults (Yamato et al., 2016). The basic reason for stroke is a partial or complete stoppage of blood flow to the brain that severely affects the brain function, consequently, the overall human body may face different types of disabilities (Tousignant et al., 2018). A stroke survivor may suffer from several long-term mental and physical impairments that have a huge impact on the patient's daily life activities (Palmerantz et al., 2017). Disabilities and their rehabilitation following stroke are generally divided into speech, cognitive and motoric impairments (Ahlin et al., 2019).

This research paper focuses on speech and language disabilities and the role of technology-enhanced systems (TES) for relearning speech and language skills. A stroke survivor's ability to communicate is reduced due to impaired reading, writing, listening, and speaking skills (Tousignant et al., 2018). A de-

creased ability to communicate has some serious consequences for the patient. One of the consequences is an unhealthy social life. The patients' social life is deeply affected where they seem to lose the pure happiness of life and often, they feel isolated from society (Ahmad et al., 2019). To reduce the depressing state of a patient's mind, the process of relearning the communication skills needs to be started as soon as possible after a stroke. Several studies highlighted the benefits of early interventions right after the stroke (Tousignant et al., 2018; Kesav et al., 2017).

Speech and language relearning requires a long-term and intensive rehabilitation plan that involves different types of treatments and exercises (Palmcrantz et al., 2017). These interventions need a lot of human and financial resources in hospitals and rehabilitation centers. However, the required resources seem not to be enough for the drastically increasing number of stroke patients (Zhang et al., 2016). Therefore, alternative interventions for speech relearning exercises must be explored.

Another important issue with traditional speech interventions is compromised independent living. Generally, stroke survivors need to stay in the rehabilitation center and they are heavily dependent on the medical caregivers to perform different kinds of exercises. Some recent studies suggested that living in the home environment has some potential benefits for the patients' overall treatment and the process of rehabilitation and relearning seems to be more efficient and effective in their own homes (Christophorou et al., 2016, Ahmad et al., 2019). In this context, the use of TES can play a vital role to perform speech relearning exercises at home.

Software applications to perform speech exercises may not only decrease the operational costs for medical caregivers, but it may also provide a sense of joyfulness and independence to the patient (Tousignant et al., 2018). However, the acceptance of these applications depends heavily on the degree of trust in TES, eHealth literacy, ease of use of software applications, and patient's integrity (De Veer et al., 2015, Ahmad & Mozelius, 2019). The software applications should be interactive, self-explanatory, and secure so that patients can easily adopt and trust them (Vassli & Farshchian, 2018).

Lack of tailor-made software applications for speech relearning exercises is also an important factor to consider. A very recent study concluded that currently used speech relearning applications in the rehabilitation centers are actually developed for the school-going children and the patients usually have different types of problems by using them (Ahlin et al., 2019). The intensity of speech deficiency differs from person to person where some patients may have some minor issues with communication, while others may not be able to speak even a few words (Egaji et al., 2019). Therefore, an individualized and tailor-made software application is needed so that it can be easily adapted according to the patients' current physical and mental condition.

Stroke is most common in adults, however, commonly used speech relearning applications are not developed from an adult's learning perspective (Ahlin et al., 2019). The adult learning theory highlighted that adults actively participate in the planning, development, and implementation of the learning process (Knowles et al., 2014). Therefore, adult learning principles should be involved in the requirement identification process.

1.1 Aim

The study aimed to gather the requirements for designing an interactive speech relearning software application for stroke survivors. The requirements were also considered from the adult learning principles' prospective.

The addressed research questions were:

1. What would be the requirements to design an interactive software application for speech relearning exercises following a stroke?
2. How can the principles of adult learning be involved in understanding the patients' needs?

2 Knowles' Adult learning theory

The adult learning theory (andragogy) highlights that adults tend to learn differently than traditional children's education that is usually referred to as pedagogy (Knowles et al., 2014). Adults should be involved in the overall process of planning and implementation of learning objectives (Knowles et al., 2005). Knowles et al. described the following six characteristics of adult learners that provide a base for an adult learning model.

2.1.1 Need to know

Adults need to know the usefulness of learning objectives before they start learning. Adults invest considerable time and energy to explore the perceived benefits of learning and the drawbacks of not learning it. Therefore, the first task of the facilitator or instructor should be to give awareness to the learner about the need to know.

2.1.2 Self-concept

Adults are usually self-directed and they like to take responsibility for their decisions. Adult learners' active participation and collaboration in the learning process is needed to enhance and stimulate their learning.

2.1.3 Learning from experiences

Adults are usually influenced by their past learning experiences that can be different from person to person. The facilitator/instructor should have a good understanding of their previous experiences and beliefs in the given field. Knowles suggests an individualized learning plan for adults according to their previous experiences.

2.1.4 Readiness to Learn

Knowles emphasizes the importance of task-oriented learning for social and professional development of adults. The perceived social benefits of a learning task increase its readiness to learn.

2.1.5 Orientation to learning

Adults tend to learn the skills that have a direct impact on their real-life circumstances. Problem-solving tasks and exercises should be involved in the learning process. The focus of learning should be problem-centered rather than subject-centered.

2.1.6 Internal Motivation

External motivation factors such as a better job, good grades in education, and a higher salary are important for learning. However, adult learning is heavily influenced by internal motivation factors such as increased quality of life, satisfaction and pleasure at work, and self-esteem. Normally adults are motivated for self-improvement and growth, however, this motivation is often compromised by lack of resources, time, and violation of adult learning principles.

2.2 The Andragogy in practice Model

Based on the adult learning principles as described in the previous section, Knowles suggested a conceptual framework that can be adopted for several adult learning practices (Knowles et al., 2014). The Andragogy in practice model is presented in figure 1. As shown in the figure, the three dimensions of adult learning in practice may influence the adult learning process.

The outer ring presents goals and purposes for learning that can be seen as developmental outcomes for the learner. The goals can be categorized into individual, social and institutional growth of the learner. The middle ring shows individual and situational differences that might have an impact on

learning practices. These differences are further categorized as individual learner differences, subject matter differences, and situational differences.

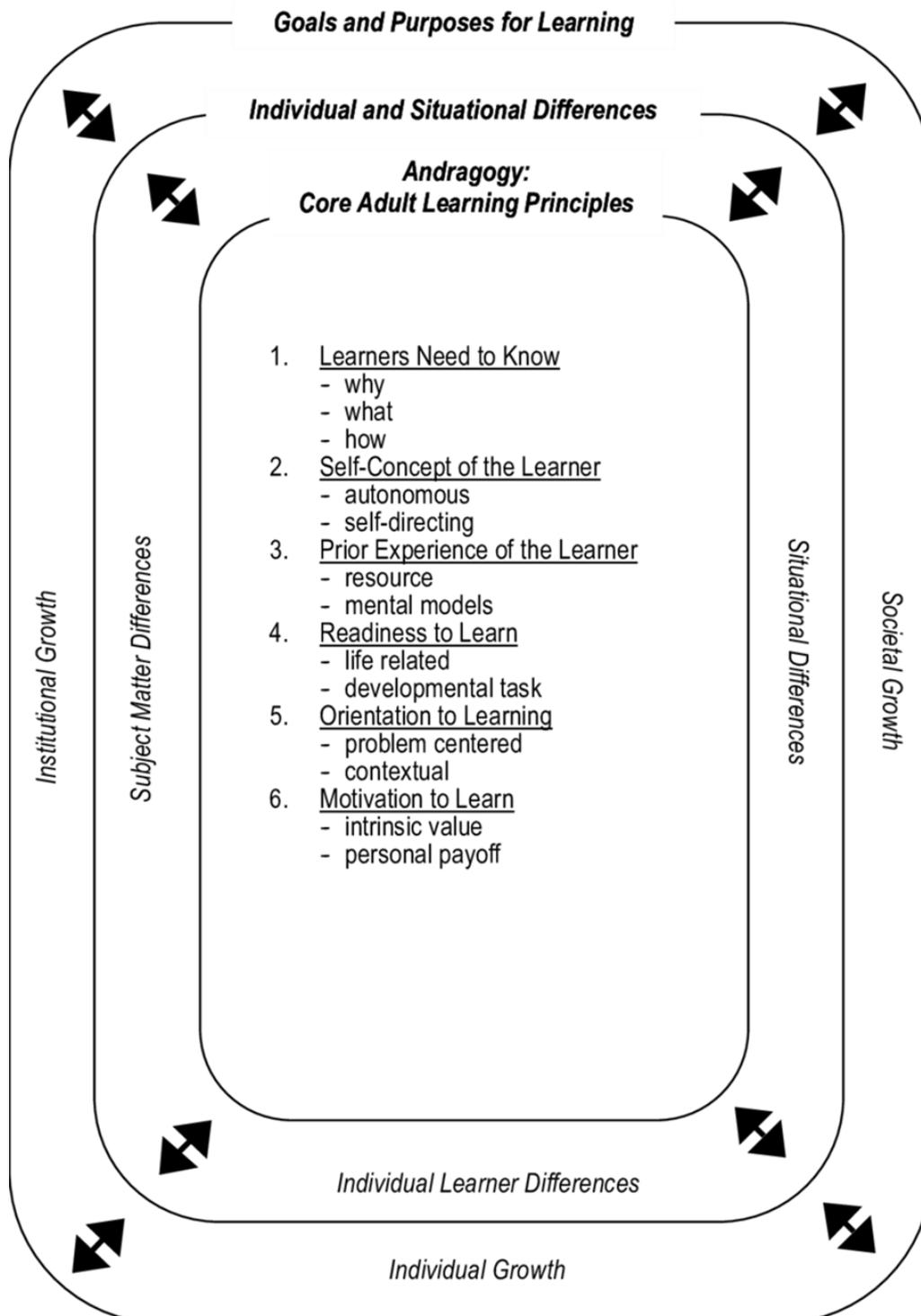


Figure 1. Andragogy in Practice Model. Source: Knowles et al. (2014). *The adult learner: The definitive classic in adult education and human resource development*, page 80. Routledge

2.3 Applied speech and language relearning framework

Several studies have successfully used adult learning principles and the andragogy in practice model for education, training, and development of adult learners (Chesbro & Davis, 2002; Kaufman et al., 2009). Since most of the stroke patients are adults, adoption of the Andragogy in practice Model seems to be a good approach for speech and language relearning. The applied speech and language relearning framework is presented in figure 2. The core six principles of adult learning were used as the base of the suggested process and the middle and outer rings of andragogy in practice model were used as filters; the core principles were examined through those filters to make the adjustments in the framework.

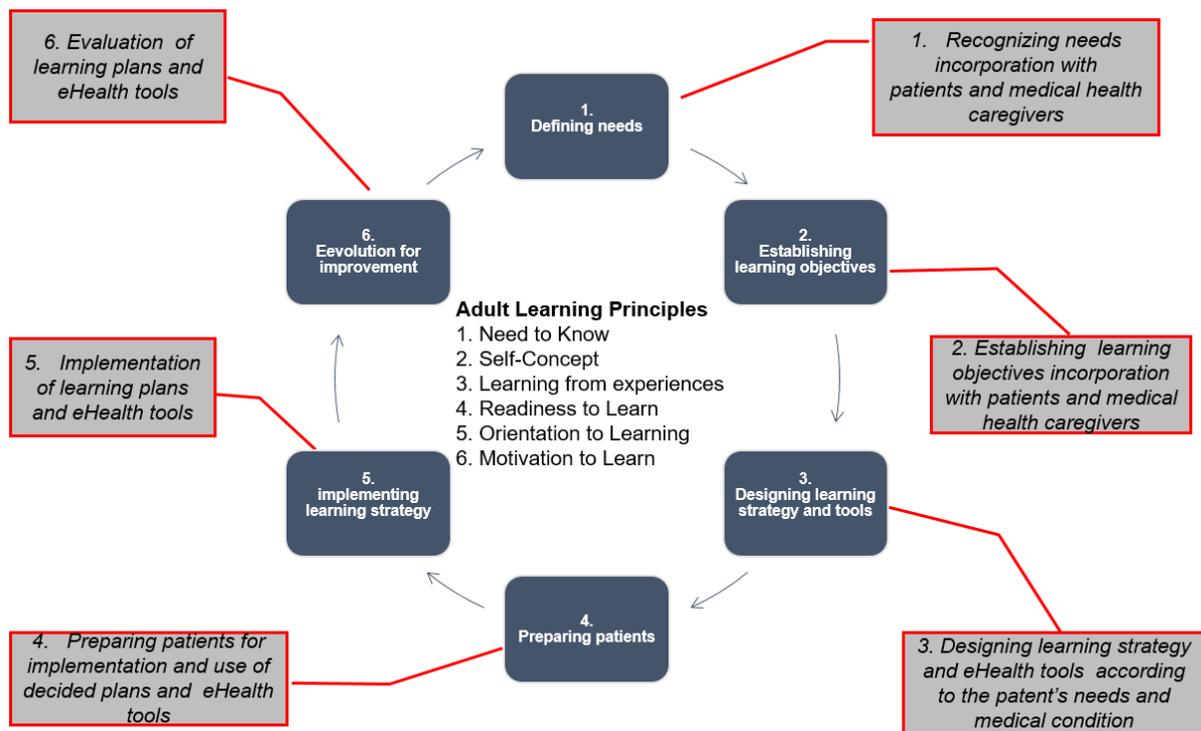


Figure 2. Applied relearning process for stroke patients

3 Method

The research methodology for this study is a design science approach that consists of a five-step process described by Johannesson and Perjons (2014). Generally, Design science consists of a rigorous process where a defined problem is solved by designing and implementing an artifact in order to make research contributions (Johannesson and Perjons, 2014; Peffers et al., 2007; Hevner et al., 2004). Since the study is about designing the requirements, a Requirement-Focused Design Science approach was adopted where the first two steps of the process were followed as illustrated below in figure 3.

Participant 5	Occupational Therapist	5
Participant 6	Physiotherapist #1	8
Participant 7	Physiotherapist #2	3
Participant 8	Chairman of the local stroke patient organization	3
Participant 9	CEO of a small company working with game-based stroke rehabilitation	25
Participant 10	Hardware and software specialist at a big multinational company	9
Participant 11	Head of Stroke Team	15

Table 1. Selected participants

3.2 Data analysis

For data analysis, an inductive thematic analysis approach was adopted as suggested by Braun & Clarke (2012). Interviews, based on audio recordings and transcripts, were carefully explored for coding, and important features of data that are directly relevant to the speech and language relearning were established. The identified codes were examined to gather the initial themes from data. The next step was to select and finalize important themes. The initial themes were thoroughly reviewed and the relevant themes that were important to answer the research question were selected. The most relevant and important themes and patterns such as independent living, tailor-made speech and language relearning, and technology acceptance were finalized that might be useful to establish the requirements for the design and development of the intended software application. The most important findings from the analysis were categorized into technical requirements, technology acceptance requirements, and social requirements.

3.3 Ethical considerations

Discussing physically and mentally impaired people has always been a sensitive issue when it comes to ethics. Ethical considerations are an important part to consider being a researcher, particularly dealing with people in the research and the consequences of the research on those people (Helgesson 2015). The Swedish Research Council (CODEX 2020) classified research ethics as professional ethics and categorized them in the following three subcategories: performing a fruitful work, following national and local rules and following the professional codes of ethics. The third subset describes considerations regarding ethics for collaboration and working environment with co-workers.

At the start of every interview, the interviewees were briefed about the consent of correspondence including some important details about their right to withdraw some specific questions or entire interview at any point. Additionally, they were informed that the purpose of gathering information through interviews is only academic research. The confidentiality of the Participant is also an important aspect of ethics (Kvale & Brinkmann, 2014). The Participants were also briefed that their personal information such as their names will not be mentioned in the research report. Moreover, the gathered data was safely stored at the university's own database where a strong password is needed for access.

Dahlbom and Mathiassen (2017) suggested a close collaboration with the user groups. In order to create a healthy work environment, the researcher should respect the user group and the users should feel satisfied and secure. Therefore, semi-structured or unstructured interviews were conducted in a very friendly environment. Medical caregivers such as speech therapists were also interviewed for requirement specification. Before conducting the interviews, there were some open discussions between the speech therapists and the researchers to exchange knowledge in their area of expertise. These discussions will help the researchers to create a healthy and secure working environment.

4 Findings

The findings are analyzed according to the Applied speech and language relearning framework, see figure 2. Here, we use step 1 - 4, where we present defining needs as what the patient's need to know, the establishing learning objectives as the patient's individual aspects, and designing learning strategy and tools as related to the patient's condition and motivation. Step #4 is presented as preparing the patient, where preparation includes both the plan as well as the TES.

4.1 The patient's need to know

Several of the informants describe the necessity to involve the patients from the beginning while discussing re-learning (Participants 1 - 4, 11). They all emphasize the importance of describing the actual situation and what they can achieve. Informant 4 describes this question as the most common second question from the patients, where the first one is if they are going to survive or not. By setting the goals, the patients can understand what they possibly can achieve by training. The actual situation is described as what happens if the patients skip their training.

Participants 1 - 4 emphasize motivation as important while discussing what can be achieved. For a person involved in managing various situations, such as being a politician or chairman, is speech of specific interest to continue activities conducted before the stroke as much as possible. Therefore, the patients need to know what they can do to live their lives as much as possible as before the stroke.

4.2 Establishing learning objectives

The basis for the patient's learning objectives are several. One is the goals and another the patient's motivation for the re-learning. Highlighted is also the patient's physical condition, which is assessed at a specific meeting with a speech therapist (Participants 1 - 2). The assessment is conducted as a standardized procedure, involving sets of detailed assignments. Before starting the standardized procedure, the speech therapists decide which parts to assess, based on the patient's described injuries. The assessment relies on an analogue procedure, developed and used in Sweden by speech therapists, and is commonly used throughout the country. Both speech therapists are keen on converting the analogue assessment process into a digital one, where the results would easily be stored and used as input for the re-learning assignments.

Besides the motivation, the stroke specialist doctor highlighted that the patient should feel a sense of pleasure and satisfaction while using software applications, therefore, goal-oriented training with the element of entertainment can improve the usability of these software (Participant 4). One suggestion, from the Chairman of the local stroke organization, is the involvement of music and dance during the relearning exercises (Participant 8).

4.3 Designing learning strategy and tools

Adults learn from their previous experiences, such as knowledge from previous experiences about TES build a perception of the use of TES. An individualized learning plan is needed for patients with different medical, social, and professional background.

Participants with medical backgrounds highlighted that the technical requirements could differ according to the patient's medical condition (Participant 1-7). Patients with impaired cognition might have problems using complex text-based interfaces. Therefore, applications with features of recording and replaying can be beneficial for those types of patients, especially for pronunciation training (Participant 1). Patients with severely impaired language skills are recommended to use image based tools, such as photographs, for communication (Participant 1, 2).

Due to the brain injuries after stroke, the patient's focus for doing different tasks is also decreased. Therefore, exercises with low intensity and a shorter span of time are more beneficial than high-intensity exercises (Participant 1, 5). In some cases, a patient's vision is blurred after stroke and they can have a limited view of things, however, the interfaces are mostly designed for the users with full vision (Participant 1, 2). Therefore, the interface should be designed according to the patient's view level. With the severe physical condition, eye-tracking technology might be helpful where patients can navigate the interface through eye movement (Participant 10).

A stroke survivor's choice of hardware also depends upon his physical condition; the software should be usable on different types of devices such as smartphones, tablets, and computers (Participant 1-3). The same requirement is suggested by the hardware and software expert, the application should be platform-independent, and it should be compatible with different kinds of hardware (Participant 10).

Two speech therapists suggested different levels of login settings for patients and medical caregivers. The software should have a simpler version of interface for the patients where they can perform their exercises, however, the speech therapists should have a detailed version where they can administer, and suggest and monitor different kinds of speech therapies (Participant 2, 3).

Many of the available software for speech are developed for English speakers, however, the speech therapies should be conducted in the native (Swedish) language (Participant 2, 11). The Head of the local mobile stroke team highlighted that the immigrants with different languages are increasing in Sweden so the stroke patients are also expected to increase, therefore, the option of selecting different languages in the software is preferable (Participant 11).

4.4 Preparing patients

After designing the learning strategy and tools, the patients should be prepared for the implementation of learning strategy. Proper education and training, usability considerations, and social aspects of TES might increase the readiness to learn for patients.

To use speech relearning exercises, education and training are also needed not only for the patients but for the speech therapists as well (Participant 2). Medical staff faced many difficulties in setting up online meetings with medical caregivers; therefore, it might be more challenging for them to guide the patients who are already facing impairments because of stroke (Participant 2, 3). Elderly people particularly face more problems while using speech relearning exercises on smartphones and tablets (Participant 1). Older adults with limited previous experience of using TES have more difficulties than the younger generation and disability after a stroke makes it even more challenging for them (Participant 1, 4-7).

Almost all the participants emphasized the importance of technology acceptance requirements such as usefulness, ease of use, adaptability, and satisfaction of the software application (Participants 1-8, 11). Two of the speech therapists informed us that there are some applications available for speech relearning exercises; however, they have not developed specificity according to stroke patient's medical condition (Participant 1, 2). The tendency to use those applications heavily depends on the degree of impairments after stroke and the overall patient's health (Participant 5-7).

Several participants highlighted the social aspects of the software (Participant 2, 5-7). The patient's close relatives and friends can play an important role in the success of a software application. One speech therapist mentioned ongoing research involving the close relatives of patients of the patients in the speech relearning process (Participant 2). That research focuses on educating and training the patient's relatives so that they will be able to help patients to perform relearning exercises. The software

should have a feature that enables the patient's relatives to collaborate with the patient as well with the speech therapist (Participant 2). An online session with the speech therapist, the patient, and the patient's close relatives such as the husband or wife of the patient can be helpful not only for the patient to perform a different kind of speech relearning exercises but for the speech therapist as well to guide the patient for those exercises.

Living independently in the home environment has some potential social benefits as well. The mobile stroke team highlighted that most of the patients want to go home as soon as possible and feel secure in the home setup (Participant 5-7). The relearning process is fast in the home environment where patients can get help and inspiration from their loved ones (Participant 2).

Personal integrity is also a matter of concern for the stroke survivors while performing therapy from distance. People do not like to be monitored all the time during the rehabilitation exercises; they want to do the exercises independently as much as possible (Participant 5-7). The patients should be able to use the application independently with the least interaction or guidance from the therapist (Participant 2, 3).

5 Discussion and Conclusion

The primary aim of this paper was to gather the requirements for the development of an interactive speech and language relearning software for stroke survivors. Some important requirements were gathered with the help of different stakeholders involved in stroke rehabilitation. Especially speech and language therapists (Participant 1-3) played an important role by describing the patients' needs according to their impaired medical condition. The secondary aim of this research was to analyze the requirements from Knowles's adult learning theory perspective. Based on Knowles et al. (2014) Andragogy in Practice Model, a framework for speech and language relearning was developed. The suggested framework shows the overall process of adult relearning after stroke, however, the first four steps were followed for this study that are directly related to requirements identification. In the following discussion, the main findings from empirical data are discussed from previous literature in the field and adult learning principles viewpoint.

Most of the participants highlighted that the requirements are different for different patients according to their physical and cognitive abilities. Several previous studies on speech and language rehabilitation also highlighted the same factor (Kesav et al., 2017, Simic et al., 2016, Rybarczyk & Fonseca, 2011). Kesav et al. (2017) argued that the intensity of relearning exercises should be according to the patient's focus or concentration level; less intensive and short exercises showed better improvement for the patients with low focus levels. Knowles et al. (2014) also highlighted that the individual differences of an adult play an important role in adult learning and an individualized learning plan is needed. Therefore, the speech therapist should be able to make an individualized relearning plan for the patients according to their medical condition. The speech therapist should have extra functionalities in software so that they can adjust the relearning exercises according to the patient's needs.

A patients-centered approach is suggested by the speech therapists; both patients and therapists should be involved in the process of software development. As highlighted by Knowles et al. (2014), adult learners should be involved in the planning and implementation of their learning objectives. Adults want to understand the learning goals before they start learning and their involvement in defining, planning and implementation of the learning process may increase the effectiveness of learning. The importance of user-central design is already a well-known factor from literature (Simic et al., 2016, Ahmad et al., 2019); however, very few studies are conducted where both patients and the therapists are involved in the software design process (Dabbs et al., 2009, Ahlin et al., 2019). The requirements should, therefore, be looked at from the user's point of view.

Several participants showed some major concerns about the usability of software applications. Medical caregivers highlighted that they faced many problems using technology-enhanced systems such as connectivity errors, audio and video efficiency, and screen sharing issues with an online meeting. Proper education and training of the given software is always an important aspect of usability (Mallet

et al., 2019). Education and training are not only important for patients but for the speech therapist as well. Usually, speech therapists recommend and educate patients about the use of rehabilitation applications, therefore, therapists need to get familiar with that application first. From the adult learning viewpoint, education and assistance about learning strategies and tools might increase the readiness to learn; the patients should be prepared for the implementation and use of selected tools and technologies for speech and language relearning.

Another important aspect highlighted by the participants is the involvement of patients' relatives and friends in the relearning process. Patients with impaired physical and mental conditions feel more comfortable, secure, and motivated if their loved ones can be involved in the relearning process. Usability and usefulness can also be improved by adding social networking features in the application where patients may connect with patients, share their stories and experience, and play online games with each other (Garcia & Manuel, 2019). The social aspects of learning are also important for adult learners, as Knowles et al. (2014) argued that the social benefits of a learning task increase its readiness to learn.

6 Future work

The study highlighted some important requirements for development of an interactive software application for speech and language relearning. The identified requirements were analyzed according to the first four steps of speech and language relearning framework. The next step would be to develop and evaluate the application according to the identified requirements where the last two steps of the relearning framework will be applied.

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