Speech and Language Relearning for Stroke Patients- Understanding User Needs for Technology Enhancement

Awais Ahmad
Computer and Systems Science,
Mid Sweden University
Östersund, Sweden
awais.ahmad@miun.se

Peter Mozelius
Computer and Systems Science
Mid Sweden University
Östersund, Sweden
Peter.mozelius@miun.se

Karin Ahlin
Computer and Systems Science
Mid Sweden University
Östersund, Sweden
Karin.ahlin@miun.se

Ali Hassan Sodhro
Computer and Systems Science
Mid Sweden University
Östersund, Sweden
alihassan.sodhro@miun.se

***Abstract*—Speech and language relearning are challenging for stroke survivors, as well as medical caregivers. After a stroke, 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 patients. Technology-Enhanced Systems (TES) can play a vital role in this context. However, the available software are not explicitly built for recovering stroke patients' needs but often for children's learning needs. This paper is, therefore, aimed at gathering requirements to support the design of speech and language relearning software applications 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. Deductive thematic analysis was conducted to analyze the main findings according to adult learning theory. The software requirements vary from patient to patient where the intensity of speech and language impairments, general medical condition, age, prior experience, and knowledge about the previous health record, and social setup of the patient are playing an important role. The speech therapists should have management functionality in the software to adjust the relearning exercises according to the patient's needs. Since, stroke is most common in adults who learn differently than children, andragogy principles were useful in recognizing patients' health conditions. Adults are interested to be involved in the development of their relearning process. Software for speech and language assessment will be helpful to establish relearning objectives for patients.**

Keywords- Requirements specification, E-Health, Stroke rehabilitation, Speech and language relearning, Adult learning theory, Independent living

I. INTRODUCTION

Stroke is one of the most common causes of death and different kinds of chronic disabilities in adults [1]. The fundamental 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 [2]. A stroke survivor often suffers from several long-term mental and physical impairments that have a considerable impact on the patient's daily life activities [3]-[6]. Disabilities and their rehabilitation following stroke are generally divided into speech, cognitive, and motoric impairments [7]-[10].

This research paper focuses on speech and language disabilities and the role of TES for relearning speech and language skills. Almost one-third of a stroke survivor's ability past learning experiences, to communicate is reduced due to impaired reading, writing, listening, and speaking skills [11]-[15]. Most impairments occur during the first weeks after the stroke, but the rest of the recovery may take several years. A decreased ability to communicate has some severe consequences for the patient. One of the consequences is an unhealthy social life [16]-[20]. The patients' social life deeply affects their quality of life; they seem to lose the pure happiness of life and often they feel isolated from society [21]-[25]. To reduce the potential risk for a patient's depressed mental state, the process of relearning 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 [26]-[30].

Speech and language relearning require a long-term and intensive rehabilitation plan that involves different types of treatments and exercises. These interventions need many human and financial resources in hospitals and rehabilitation centres. The goal of Speech and Language Therapy (SLT) is to improve the patient's speech and language abilities [31]-[34]. There is some evidence that highly intensive, highly dosed, and long-term therapy have better results as compared

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to low intensity, low dosed and short-term therapy [35]-[39]. The content of the SLT relates to the stroke patient's damage and intention, such as trying to get back to their speech before the stroke or withholding the current situation. One example of SLT is object identification, classified as simple or complex order comprehension. Simple order comprehension can be to "Put the glass close to the plate" and complex "Put the glass close to the plate and the glass close to a fork." However, the supply of required resources seems not to be enough for the drastically increasing number of stroke patients [40]. Therefore, alternative interventions for speech relearning exercises must be explored. Another critical issue with traditional speech interventions is compromised independent living. Generally, stroke survivors need to stay in the rehabilitation centre, and they are heavily dependent on medical caregivers to perform different kinds of exercises. Various studies suggested that living in the home environment has potential benefits for the patients' overall treatment; in fact, the process of rehabilitation and relearning seems to be more efficient and effective in their own homes [41]. 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 [42]. 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. The software applications should be interactive, self-explanatory, and secure so that patients can quickly adopt and trust them [43].

Lack of tailor-made software applications for speech relearning exercises is also an essential factor to consider. Authors' previous studies highlighted that currently used speech relearning applications in rehabilitation centres are actually developed for school-going children rather than adults [4]-[15]. Stroke patients usually face difficulties using these applications, because of differences in context and learning behaviors between adults and children [4]-[16]. The intensity of speech deficiency differs from person to person where some patients may have some minor issues with communication. In contrast, others may not be able to speak even a few words [44]. 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 [45]-[47]. The adult learning theory highlights that adults actively participate in the planning, development, and implementation of their learning process [48]. Therefore, adult learning principles should be considered in the requirement identification process.

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' perspective. The addressed research questions were:

1. What are the requirements for designing an interactive software application for speech relearning exercises following a stroke?

2. How can the principles of adult learning support understanding the patients' needs?

The remaining paper is organized as follows. Section II, addresses the Knowles' adult learning theory model, Andragogy in practice model is presented in Section III. Method is presented in Section IV, while findings and discussion are presented in Sections V and VI respectively. Finally, conclusion and future work are discussed in Section VII.

II. KNOWLES' ADULT LEARNING THEORY

Several studies have successfully used adult learning principles and andragogy (adult learning theory) in the practice model for education, training, and development of adult learners [13]-[19]. Andragogy highlights that adults tend to learn differently than the traditional children's education that is usually referred to as pedagogy [15]. Adults should be involved in the overall process of planning and implementation of learning objectives [20]. Knowles et al. described the following six characteristics of adult learning model that is guidance for them [15].

A. Need to know

Adults need to know the usefulness of learning objectives before they start learning. Adults invest considerable time and energy in exploring the perceived benefits of learning compared to the drawbacks of not learning. Therefore, the first task of the facilitator or instructor should be to bring the need to know to the learner's awareness.

B. Self-concept

Adults are usually self-directed, and they like to take responsibility for their decisions. A person tends to shift his or her self-concept from dependency towards self-direction. Adult learners' active participation and collaboration in the learning process is needed to enhance and stimulate their learning.

C. Learning from experiences

Adults are usually influenced by their past learning experiences, which vary from person to person. The facilitator/instructor should have a good understanding of an adult's previous experiences and beliefs in the given field. Knowles suggests an individualized learning plan for adults according to their previous experiences.

D. Readiness to learn

Knowles emphasizes the importance of task-oriented learning for the social and professional development of adults. The perceived social benefits of a learning task increase its readiness to support learning. The adults feel an urge to learn when they realize their changed circumstances and the role of learning in these situations.

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E. 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-centred rather than subject-centred.

F. Internal motivation

External motivation factors, such as a better job, good grades in education, and a higher salary are essential 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. Usually, adults are motivated for self-improvement and growth; however, this motivation is often compromised by a lack of resources, time, and violation of adult learning principles.

III. THE ANDRAGOGY IN PRACTICE MODEL

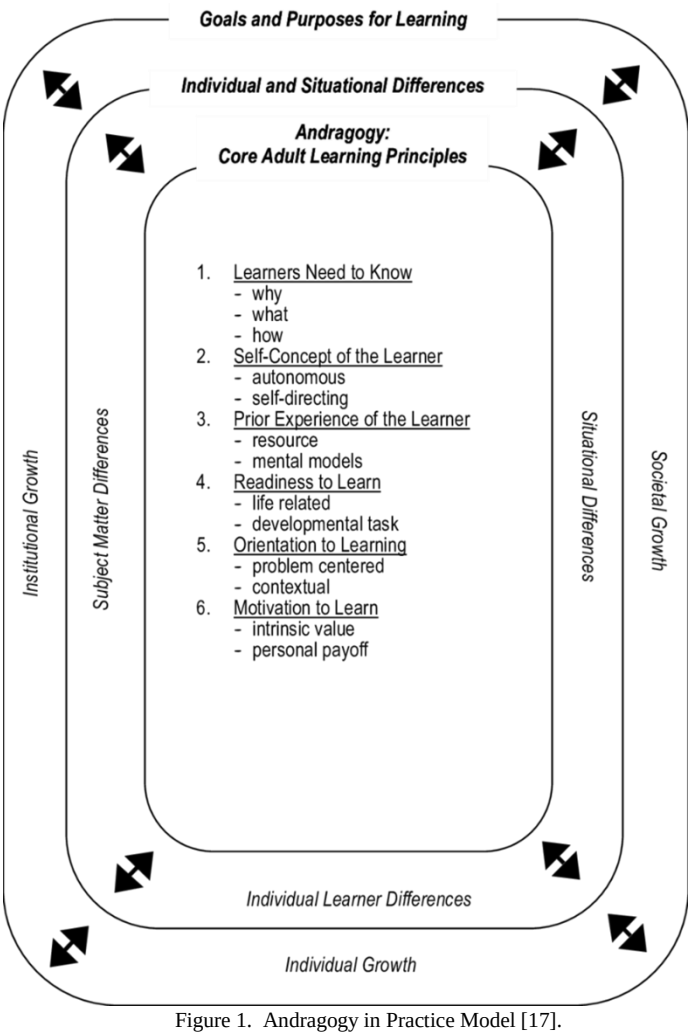

Figure 1. Andragogy in Practice Model [17].

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 [15]. Since, most of the stroke patients are adults, adoption of the Andragogy in Practice Model (APM) is a promising approach for speech and language relearning as shown 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. The core six principles of adult learning were used as the primary themes that highlight patients' need for technology-enhanced speech and language relearning. The middle and outer rings of andragogy in practice model were used as filters; the core principles were examined through those filters to the requirements for the technology-enhancement following stroke.

IV. METHOD

The research methodology for this study is a design science research (DSR) that consists of a five-step process described by researchers in [24]. Generally, DSR consists of a rigorous process where a defined problem is solved by designing and implementing an artefact in order to make research contributions [21]-[23]. 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.

A. Data collection

Interviews are the most common approach for data collection and defining the requirements. Semi-structured interviews were conducted with some important stakeholders. The selection of participants is a tedious but essential part of the data collection process. The selection of highly competent and enthusiastic participants plays an essential role in the requirements specification [24]. A purposive sampling approach was adopted for the selection of participants, where all of the participants should have good knowledge and expertise in speech rehabilitation. Interviews were conducted with 11 participants; their professional role and experience in the related field are described below in Table 1. Participants 2-7 were interviewed several times for detailed information and requirements identification.

B. Data analysis

For data analysis, a deductive thematic analysis approach was adopted as suggested by [29]. Interviews, based on audio recordings and transcripts, were carefully explored for coding, and essential features of data that are directly relevant to speech and language relearning were established. The identified codes were examined according to the adult

learning theory described in the previous section, and the initial themes were gathered from data. The next step was to select and finalize essential 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 essential themes, such as independent living, tailor-made speech, and language relearning, and technology acceptance was analysed and presented according to Knowles adult learning principles.

TABLE I. STUDY PARTICIPANTS

Participants	Professional role	Years of experience
Participant 1	Speech therapist #1	25
Participant 2	Speech therapist #2	4
Participant 3	Speech therapist #3	5
Participant 4	Stroke specialist doctor and manger in the regional hospital	25
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

C. Ethical considerations

Discussing physically and mentally impaired people has always been a sensitive issue when it comes to ethics. Ethical considerations are essential as a researcher, mainly dealing with people in the research and the consequences of the research on those people [26]-[29]. The Swedish Research Council [30]-[35] 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 [36]-[39]. 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 crucial 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 essential aspect of ethics [28]. 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 database, where a strong password is needed for access.

Authors in suggested a close collaboration with the user groups [29]. 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 interviews were conducted in a warm 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. The article has been peer-reviewed and discussed at the 43rd Information systems research seminar in [33].

V. FINDINGS

The findings were analyzed thematically according to the Knowles Andragogy in Practice Model (APM); as shown in Figure 1. The patients' needs for technology enhancement are presented using adult learning principles as core themes. The adult learning theory and its principles were described to the speech therapist in regional rehabilitation (Participants 2). Supersizing, they have been considering speech and language from the adult learning aspects without knowing those principles, and they endorsed the idea of involving these principles for technology-enhanced speech and language relearning.

A. The patient's need to know

Several informants describe the necessity to involve the patients from the beginning while discussing relearning (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 to 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.

The bases for the patient's learning objectives are several. One is the goals and another the patient's motivation for relearning. 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

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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 relearning assignments.

B. Self-concept of patients

Since adults are usually self-directed, they would like to take responsibility for getting the information about their disabilities and the process of recovery. Several participants highlighted that patients like to get information from their relatives and friends (Participant 2, 5-7). Therefore, the patient's close relatives and friends can play an essential role in the success of a technology-enhanced system. One speech therapist mentioned ongoing research involving the close relatives of 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 as 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.

Personal integrity is also a matter of concern for the stroke survivors while performing therapy from a 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).

C. Adult patients learn from their experiences

Adults learn from their previous experiences, such as knowledge from previous understandings about TES build a perception of the use of TES. It is, therefore, essential to consider patients' previous practices and knowledge about technology enhancement. Many of the available software for speech is 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 number of immigrants with different languages is increasing in Sweden and healthcare givers need more and more resources for translation services. Therefore, the option of selecting different languages in the software is preferable (Participant 11).

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). Older 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).

D. Readiness to learn

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

Two speech therapists suggested different levels of login settings for patients and medical caregivers. The software should have a simpler version of the 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). 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 this 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).

E. Orientation to learning

The relearning strategy should be individual-focused rather than disability-focused. Therefore, 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 and their perception about the use of technology enhancement (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 period 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).

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Therefore, the interface should be designed according to the patient's view level. With 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).

F. Internal Motivation of patients to relearn

Participants 1 - 4 emphasized that internal motivation is essential while discussing what can be achieved. For a person involved in managing various situations, such as being a politician or chairman, is the 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.

Living independently in the home environment has some potential benefits for stroke survivors as it increases their internal motivations for relearning. 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).

VI. DISCUSSION

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 essential 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 of Knowles's adult learning theory perspective. Some other related studies also highlighted the involvement of adult learning principles in the speech and language relearning process might increase the efficiency and effectiveness of relearning for stroke patients [31][32]. Andragogy in Practice Model [15] was used as a theoretical framework for speech, and language relearning was developed. 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 [6][33][34]. Researchers in [44-45] 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 levels6. Authors in [46-48] also highlighted that the individual differences of an adult play an essential role in adult learning, and an individualized learning plan is needed [15]. 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.

Speech therapists suggest a patient-centered approach; both patients and therapists should be involved in the process of software development. As highlighted by [17], 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 the literature [5][33]; however, very few studies are conducted where both patients and the therapists are involved in the software design process [4][35]. The requirements should, therefore, be looked at from the user's point of view.

Several participants showed some significant concerns about the usability of software applications. Medical caregivers highlighted that they faced many problems using Technology-Enhanced Systems (TES) 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 essential aspect of usability [36]. Education and training are not only crucial for patients but 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 [13][18][37]. 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 [38]. The social aspects of learning are also crucial for adult learners, as discussed in [42-43], they argued that the social benefits of a learning task increase its readiness to learn.

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 [2][39-42]. 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 [43-45]. The software applications should be interactive, self-explanatory, and secure so that patients can quickly adopt and trust them [46-48].

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VII. CONCLUSION AND FUTURE WORK

With the help of some experienced and enthusiastic participants, some essential requirements for technology-enhanced speech and language relearning were gathered. Since stroke is most common in adults and adults learn differently than children, adult learning theory was helpful to understand the patients' needs. Adult patients like to involve in the development of their relearning process. Therefore, a speech and language assessment software should be the first step in technology enhancement where a speech therapist can show the patients the level of their current and/or previous impairments and plan a future strategy for their relearning.

The relearning process should be decided according to patients' internal and external circumstances such as the general medical condition of the patient, intensity of speech and language impairments, and patient's social and professional life. Therefore, speech therapists need extra management functionality in the relearning software so that they can adjust the exercises according to the patient's needs.

This study found essential requirements for the future development of technology-enhanced applications for speech and language relearning tailored for stroke patients. The next planned steps are to design, develop, and evaluate two technology-enhanced applications to support the diagnosis and the relearning process after stroke. Both these applications should be designed and tested with a multi-stakeholder approach involving caregivers, software developers, stroke patients, and stroke patients' friends and family. To carry out the work with a multi-stakeholder approach is essential since a stroke patient's speech relearning journey back to an independent life is a long and tedious one.

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