The Possibilities of Smart Clothing in Adult Speech Therapy: Speech Therapists' Visions for the Future

Johanna Nissinen
Faculty of Social sciences
Tampere University
Tampere, Finland
annijohannanissinen@gmail.com

Severi Konttinen
Faculty of Social sciences
Tampere University
Tampere, Finland
severi.konttinen@tuni.fi

Emmi-Lotta Rauhala
Faculty of Social sciences
Tampere University
Tampere, Finland
emmi-lotta.rauhala@tuni.fi

Charlotta Elo
Faculty of Social sciences
Tampere University
Tampere, Finland
charlotta.elo@tuni.fi

Johanna Virkki
Faculty of Medicine and Health
Tampere University
Tampere, Finland
johanna.virkki@tuni.fi

Tiina Ihalainen
Faculty of Social sciences
Tampere University
Tampere, Finland
tiina.ihalainen@tuni.fi

***Abstract*— The potential of technology in healthcare has been closely explored in recent years. Increasingly more innovative technology-assisted rehabilitation methods for various customer groups are constantly being developed. However, the possibilities of smart clothing in adult speech rehabilitation have not been previously studied. The purpose of this study was to discover speech therapists' visions about the possibilities of smart clothing in adult rehabilitation. We organized an ideation workshop in December 2020 with four speech therapists who had worked in adult rehabilitation for at least five years. The workshop was held online on the Zoom platform. In the workshop we presented three questions for the speech therapists: 1) Which adult speech therapy clients could benefit from smart clothing? 2) What could smart clothing be used for in speech therapy rehabilitation for adults? and 3) How could smart clothing be used in speech therapy rehabilitation for adults? Qualitative data from this research was analyzed by thematic analysis. The main results of this study were that patients with dysphagia and patients with voice disorders were seen as the groups with the greatest potential use smart clothing, and continuous registration of various physiological functions of voice and swallowing were voted as the most usable applications of smart clothing. The most discussed topics were using smart clothing to monitor rehabilitation and using the clothing to activate and motivate the client by giving feedback. And finally, the easiest ways to control smart clothing were seen to be body movements, gestures, and touch.**

Keywords – smart clothing, technology-assisted rehabilitation, speech therapy, adult rehabilitation, health technology

I. Introduction

Speech therapy is therapeutic treatment of impairments and disorders of language, communication, voice, speech motor control, and swallowing. The goal of speech therapy is to understand the nature of a client's difficulties caused by disease or trauma and facilitate and promote the client's abilities [1]. One of the largest client groups for speech therapy is people with communication disorders. Communication disorders are a large field of different disorders affecting a person's language, speech, fluency, and social communication. Speech and language disorders are one area of communication disorders. Language disorder refers to an impaired ability to understand and/or use words right [2] and speech disorder affects the ability to produce speech sounds or normal voice, or to speak fluently [3]. Speech and language disorders, such as aphasia, dysarthria, and apraxia of speech, are often a result of damage to the brain or the peripheral nervous system that regulate the speech mechanism [4].

Speech therapists also rehabilitate voice disorders, which an individual's phonation is irregular or disordered [5]. Voice disorders can be organic, functional, or neurologic [6]. Insufficient or improper use of vocal mechanisms may lead to the development of voice disorders [5]. The most usual instruments used in a clinical speech laboratory measure an acoustic signal, aerodynamic alternatives of pressure or flow, or visual images of vocal lip vibration [7]. In addition, applications such as TheraVox and SpeechVive can also measure features of the voice, and thus provide biofeedback and real-time information to the voice user [8]. Among other applications available are the ambulatory phonation monitor (APM; KayPENTAX, NJ), VoxLog (Sonvox AB, Umeå, Sweden) and VocaLog (Griffin Laboratories, CA) [9].

One significant group of speech therapy clients is patients with swallowing difficulties, that is, dysphagia [10] – [15]. Dysphagia refers to a difficulty to transferring food from mouth to stomach safely [14]. One of the most severe symptoms related to dysphagia is aspiration, which means entry of swallowed material into airways below the vocal folds [14]. Several different applications have been developed for the assessment and rehabilitation of swallowing functions. For example, reference [16] developed a non-invasive swallowing measurement device that uses combination of respiratory flow, swallowing sound, and laryngeal motion to measure features of swallowing. In addition, reference [17] developed a non-invasive skin-mountable sensor patch which monitors muscle activity and laryngeal movement during swallowing tasks and maneuvers. Reference [18] developed a non-invasive device that monitors chewing and swallowing based on sounds detected by a sensor. Furthermore, Swallowscope is a smartphone-based device which is a real-time swallowing sound processing algorithm developed for automatic screening, quantitative assessment, and visualization of swallowing problems [19]. The device can be used in everyday life and it´s able to detect risk of aspiration and risky swallowing patterns through continuous monitoring.

Speech therapy rehabilitation is often hampered by both economic and practical reasons. Rehabilitation requires a lot of face-to-face therapy with a clinician; consequently, a lot of employee resources are used for one client [20], [21]. Moreover, clients living in remote areas have less access to rehabilitation. Technology-assisted rehabilitation could provide a partial solution to the problem of scarcity of speech therapy resources [22]. The growing interest in technological rehabilitation methods and aids over the years is understandable, as modern intelligent devices facilitate planning rehabilitation, the preparing rehabilitation exercises and adapting of rehabilitation methods to individual needs [23], [24]. Some wearable solutions have been developed for speech therapy, but these solutions are not yet widely used. For example, there has been developed a communication glove with wireless sensors capable of detecting various finger movements [25], an interpreter glove for people with speech impairment disability through audible speech producing software [26], a smart glove for deaf and mute people [27], a hand-gestures-translated-into-speech glove solution [28] and a hand Braille glove developed for visually impaired people [29]. With these above-mentioned applications the complexity and expensiveness of the operating systems and the practical challenges of an active power supply have been identified as problems in using the applications.

Further, gamification of speech therapy has been found to be an effective way to enhance rehabilitation. Reference [30] found that people with Parkinson's disease benefited from visual feedback given in the form of interactive games when training articulatory movements. In addition, reference [31] found that principles of video games enhance rehabilitation effects in many ways by affecting clients learning and motivation. The principles of video games could well be applied for the principles to smart clothing in speech therapy because smart clothing can be connected to smart devices and their applications.

A potential new solution for developing wearable clothing lies in passive radio frequency identification (RFID) technology [32] – [34]. With the RFID technology, clothing can detect body movements and various contacts on the surface of the clothing. For example, the garment can be connected to a mobile device, such as a smartphone or tablet computer, with a built-in RFID reader. In this way, smart clothing can use applications developed for a mobile device, for example. Smart clothing that uses RFID technology does not require its own separate power supply but receives the power it needs from the RFID reader of the connected smart device, or an RFID reader placed elsewhere in the environment and connected to the smart device [35] – [37]. Thanks to RFID technology, the intelligence can be inconspicuously integrated into the user's everyday clothing. The technology used in smart clothing is also resistant to washing and consumption. In addition, the technology used by this smart clothing has the advantage of its low cost, as the price of a single microchip is only a few cents. In this study, we wanted to find out how such smart clothing could be used in adult speech therapy rehabilitation in the future, in the opinion of speech therapists. This study provides new insights into smart clothing development work, enabling the development of more diverse future rehabilitation methods in adult speech therapy.

II. Methods

A. Ideation Workshop

The ideation workshop was held in December 2020. The implementation platform of the ideation workshop was the Zoom video meeting service. In an ideation workshop, participants always have a common goal to achieve through their discussion [38]. The aim of this study was to come up with possibilities of utilizing smart clothing in adult speech therapy rehabilitation in the opinion of speech therapists. Ideation together is a productive way to create something new, and participants can perform tasks better together in a group than when working alone [39]. With the help of collective intelligence, an ideation workshop can create ideas that could be left out, for example, in surveys or individual interviews.

The questions presented in the ideation workshop were: 1) Which adult speech therapy clients could benefit from smart clothing? 2) What could smart clothing be used for in speech therapy rehabilitation for adults? and 3) How could smart clothing be used in speech therapy rehabilitation for adults? The questions provided a framework for discussion and ideation. For each question, the actual ideation session began with a ten-minute silent ideation session. During this time, participants were allowed to write their ideas in the text box on a shared screen. Due to time constraints, the researchers emphasized that participants should not think about the feasibility of their ideas in practice. In this way, participants were encouraged to have plenty of creative ideas. After silent ideation, participants were asked to discuss freely the ideas they wrote down. According reference [38], more than half of the working time of the ideation workshop should be used for this free and creative brainstorming. This was also the case in this ideation workshop. Researchers participated in the discussion by asking more specific questions, asking for more information about some ideas, or sharing their own thoughts.

At the end of the ideation workshop, participants were given a view of previously co-produced ideas, and they were allowed to vote for the best and the most challenging idea in every question. This made it possible to evaluate and further develop the ideas produced in the ideation workshop [38]. Finally, participants were offered the opportunity to ask questions and to provide feedback. The ideation workshop work was recorded, and screenshots were taken of the ideation slides produced in the workshop. The ideation workshop lasted about two and a half hours, with a short break halfway through.

B. Participants

Four speech therapists who had worked in adult speech therapy rehabilitation for at least five years participated in this study. Participants were recruited through a general call for applications stating the nature of the study and the criteria for participation. The recruitment notice was distributed on social media within groups targeted at speech therapists, through the Finnish Speech Therapists' Association to its members, and by e-mail to potentially qualified speech therapists. In qualitative research, it is more important from whom the information is collected than how many participants there are [38]. Therefore, it makes sense to use so-called elite interviews.

Participants were volunteers and all of them provided a written informed consent. The average age of the participants at the time of the study was 35 years (range 31–40 years). At the time of the study, participants had an average of 9.5 years (range 6–13 years) of work experience as a speech therapist. Two of the participants worked in the public sector and two in the private sector. Participants reported that the most common client groups in their daily work were adult clients with dysphagia, motor speech disorders, aphasia, apraxia of speech and dysarthria.

C. Analysis of Workshop Data

The data from the ideation workshop was spelled out and reviewed by two researchers, so that collaboration and individual perspectives were likely to increase the versatility and accuracy of the data analysis. The discussion recorded from the ideation workshop was transcribed according to the principles of basic transcription word by word in the spoken language. Participants' minimal feedback as well as filler words and individual pronunciations were removed. After that, both the transcribed discussion and the ideation slides were analyzed qualitatively by means of thematic analysis [40]. The aim of the content analysis was to clarify and summarize the key information of the collected data [41]. The research data was reviewed as a whole several times by two researchers (XX and XX) in order to form a coherent picture of the collected data. The research data was then divided into different themes based on the data. Next, the data was reviewed question by question. At this stage, it was also ensured that each corresponding idea was placed with the right question. In this way, the final categories were formed, under which all the ideas that emerged in the study were meaningfully placed [41]. The categories of results were formed based on data. The most discussed ideas are presented in this article.

III. RESULTS

A. Which adult speech therapy clients could benefit from smart clothing? - Speech therapist's visions

In the ideation workshop, the most discussed potential user groups of smart clothing were patients with dysphagia, voice disorders and apraxia of speech. Additionally, individuals with developmental disabilities or neurodegenerative disease were seen as potential users. One specific potential user group was patients with tracheostomy – an opening created at the front of the neck so a tube can be inserted into the windpipe to help patient breathe. The participants voted patients with dysphagia and voice disorders to be the most suitable users of smart clothing. Respectively, patients with aphasia, apraxia of speech or dementia and individuals with developmental disabilities were voted to be the most challenging user groups. The most discussed user groups are listed in Table 1.

TABLE I.

Which adult speech therapy clients could benefit from smart clothing?
General groups
• patients with
– cognitive and motor disabilities
– unawareness of their symptoms
– oral and speech motor disorders
– executive function disorder
• all patients who have something to rehabilitate
• elderly people
• people who use augmentative and alternative communication (AAC)
• remote speech therapy clients
Specific disease and disability groups
• patients with
– neurogenerative disease (e.g., Parkinson`s disease, amyotrophic lateral sclerosis (ALS))
– dementia
– dysphagia
– voice disorders
– functional vocal cord dysfunction
– irritable larynx syndrome
– respiratory arrest
– tracheostomy: permanently tracheostomized, tracheostomy weaning
• individuals with
– developmental disabilities
– reduced mobility
– autism
– aphasia
– apraxia of speech
– brain injury
– fluency disorders (e.g., stuttering, cluttering)
• patients recovering from stroke

B. What could smart clothing be used for in speech therapy for adults? - Speech therapist's visions

As seen in Table 2, the speech therapists came up with several ideas about what smart clothing could be used for in speech therapy. One of the most discussed ideas was that smart clothing could be used to monitor rehabilitation and to activate and motivate the client, for example, by giving feedback. The feedback could be visual, auditory, or haptic. According to the speech therapists, smart clothing could be used especially for voice and dysphagia rehabilitation to monitor and measure different physiological variables (e.g. to measure laryngeal muscle activity or to measure the number of swallows). Physiological measurement and feedback were voted the most useful purposes for smart clothing. Using smart clothing to give instructions to the client, to support communication, to use as an augmentative and alternative communication method and to rehabilitate an individual with severe disabilities were voted to be most challenging problems to solve with smart clothing. The uses of smart clothing that sparked the most discussion in the ideation workshop are listed in Table 2.

TABLE II.

What could smart clothing be used for in speech therapy rehabilitation for adults?
Rehabilitation monitoring
• to collect biofeedback and number of repetitions
• to provide visual, auditory, and haptic feedback
• to monitor rehabilitation (swallowing exercises performed by caregivers and assistants)
• to record and monitor the effectiveness of rehabilitation (what happens in rehabilitation, exercises performed in rehabilitation, and the development of range of motion and muscles)
• to register the patient´s activity (information from a longer period)
• to monitor how the instructions are implemented in everyday life
• to visually illustrate the progress of the rehabilitation (e.g., bar chart)
• to measure participation in communication situations (presence of another person and use of voice)
• to gather information about everyday problems, for example, in eating, swallowing or communicating – targeting rehabilitation based on gathered information
• to observe the client in everyday life, and to remind the client, for example, slow down if they eat too fast
Motivating and activating the client
• to motivate client with feedback, e.g., the number of repetitions
• to activate the client in such a way that they perceives their own communication as meaningful
• to motivate the client, for example, in swallowing rehabilitation, when the client receives visual feedback
• to motivate the client by illustrating the relevant milestones of rehabilitation
Rehabilitation of voice
• to register voice (vocal vibration, pitch, couching, volume of voice, voice quality)
• to record laryngeal muscle activity (range of motion, frequency, muscle movements in relation to each other)
• to replace Voxlog
• to register vocal cord dysfunction (VCD) scenes and spasmodic dysphonia
• to measure hyperfunctional voice
• to monitor rehabilitation of voice
• to raise patient`s awareness of their vocal behavior
• to provide feedback on the volume
Rehabilitation of swallowing
• to register swallowing sounds (connection to cervical auscultation)
• to measure the number and quality (effectiveness and duration) of swallows, and to monitor fatigue
• to register laryngeal muscle activity (range of motion, frequency, muscle movements in relation to each other)
• to register and guide the patients if they keep food in their mouth without swallowing
• to assess swallowing, information from the longer term
• to register and identify signs of aspiration (coughing, increased pulse, increased respiratory rate, watery eyes, discomfort)
• to register signs of silent aspiration and to alert if there is an increased risk of silent aspiration
• to record patient's aspiration and number of cough reactions during meals, this information could be stored in the patient information system to give objective and reliable information to the speech therapist
Rehabilitation of communication
• to record, visualize and clarify dysarthric speech
• to give a metronome-like rhythm to speech if speech becomes slurred or dysrhythmic
• to rehabilitate language
• to communicate
• to observe communication initiatives - register information for the speech therapist
• to give experience of the ability to communicate with others
• to rehabilitate stuttering – smart clothing could give delayed audio feedback without a sperate device or application
• to give sensations, such as feeling of pressure
• to rehabilitate an individual with a lack of initiation
• to rehabilitate an individual with severe disability – rehabilitation would begin with practicing gaze use and pointing gestures
• to illustrate pointing gestures to the speech therapist
Augmentative and alternative methods (AAC)
• to use AAC-material
• to teach the meaning of gestures to the client
• to act as speech-generating device
• to interpretate the client's gestures and facial expressions
• for quick drawing communicating system
Reminders
• to remind to do / not to do something
• to remind client if they speaks jargon or inappropriately
• to support working memory
Special ideas
• to take a surface electromyography (EMG)
• for smart tracheostomy
• to improve symptom awareness
• to instruct the patient
• to bring rehabilitation into everyday life with the help of smart clothing
• to create better application possibilities and the implementation of a larger amount of rehabilitation
• for independent delivery of transcutaneous electrical stimulation by means of smart clothing

C. How could smart clothing be used in speech therapy for adults? - Speech therapist's visions

Body movements, gestures and touch were seen as a good way to use smart clothing (Table 3). In addition, smart clothing was seen as a means of gathering information from clients and their activities. In this context, smart clothing was seen as being able to learn from the data it collects and to modify and personalize functionalities based on the data. The participants voted continuous registration of various physiological functions of voice and swallowing as the most usable idea for smart clothing in speech therapy. The most popular garment named in the ideation workshop was a shirt with a high collar or just a collar. Those were seen as optimal, especially when assessing swallowing and voice production (e.g., registration, surface EMG), since collars are close to the neck.

TABLE III.

How could smart clothing be used in speech therapy rehabilitation for adults?
Use of smart clothing
• by surface EMG
• by touch /other sensory experience
• by body movements
• by pointing at an object and sound being produced from the speakers
• by using gestures, smart clothing could translate gestures to speech, for example, a word "saw" could be produced by showing gestures for sawing

• to interpret body gestures, for example, when a person has something to say, they moves the foot, causing the smart sock on the foot to react to the movement. • like in the game *Pictionary*, by drawing in the air • images of the user`s everyday things could be quickly stored in the smart clothing, so that the user could see them, for example, on the sleeves, and they could be quickly edited • a computer program that receives information about smart clothing and with which patient can control the functions of the smart clothing e.g. the images it contains, the amount of pressure sensation, the optimal point for messages • as transcutaneous electrical stimulation
Operation of smart clothing
• the smart clothing could learn from the collected data, for example that a stronger message needs to be given or that the image is in the wrong place and that the client is not hitting the image`s position • smart clothing would collect data about the client's activities and then optimize smart clothing as the most effective rehabilitation tool possible • by vibration • by visualizing registered communication initiatives as visual maps, images, or bar charts • smart clothing could translate the spoken speech into visual form • a contact microphone could measure surface vibration, providing lower-frequency information from speech without air pressure variation • to record an audio signal
Garment
• polo shirt • polo shirt collar /collar • ear button • a helmet cap that would take voice and give information to an ear • smart commando hat, whole face area • combined with smart glasses • in smart glasses • combined with a headset • glove
Other ideas
• for gamification and competition in rehabilitation • would not require additional rehabilitation equipment (clothes are always included)

IV. DISCUSSION

A. Most suitable user groups and intended uses for smart clothing in adult speech therapy

In the workshop, the participants voted patients with dysphagia and patients with voice disorders to be the most suitable users of smart clothing. Swallowing and voice production are physiological phenomena, which can be measured, and this may be a reason that participants saw measurement of these phenomena as the best uses for smart clothing. Physiological measurement was also seen more broadly as a potential use of smart clothing. Participants voted it the best way to use smart clothing, as part of a more general set of practices of measurement, continuous registration, and feedback in rehabilitation.

Participants ideated that the number, effectiveness, duration, and fatigue of swallows could be measured by smart clothing. Further, smart clothing could detect signs of aspiration (e.g. coughing and voice changes related to swallowing) and alert if there were signs of aspiration. Consideration of the potential of smart clothing in swallowing evaluation is justified because the use of high technology in the evaluation of swallowing functions has been identified in previous studies. For example, there is a non-invasive swallowing measurement system that uses a device that detects features such as respiratory flow, swallowing sound, and laryngeal movement to monitor swallowing [16]. In addition, reference [17] developed a skin-mountable sensor patch, which monitors muscle activity and laryngeal movements during swallowing. RFID-based smart clothing could potentially help assessment in the same way by detecting muscle movements [33], [34]. Also, a device that registers swallowing sounds with a sensor located above the laryngopharynx has been developed [18]. Similarly, participants in our workshop suggested that smart clothing could use technology to record swallowing sounds and, that way, possibly also respond to cervical auscultation. In the workshop, smart clothing was also seen as a way to collect data from the client for the speech therapist, as in the study [19], in which a smartphone collected and transferred information from patient to therapist. In this way, the swallowing data for the long term could be collected, which was also one speech therapist's vision in our workshop. When considering the possibilities of smart clothing bringing to patients the benefits and uses of the noninvasive dysphagia evaluation methods developed before, the practitioners could see opportunities for very similar activities, as smart clothing is able to detect movements and contacts on the garment surface using RFID technology [32 – 34]. Ideas mentioned above, if they materialized, could save clinician resources, and reduce the subjectivity of assessments, which could also increase the reliability and accuracy of the assessment.

Participants also ideated that smart clothing could register and measure voice features and behavior using a one's voice. Smart clothing can thus be envisioned to work the same way as earlier developed voice applications TheraVox and Speech Vive, which can measure the features of voice, and thus could give biofeedback and provide real-time information to the voice user [8]. The participants in our study suggested that smart clothing and its applications could replace VoxLog, which is a collar-based application for voice registration [9]. VoxLog also registers background noise, and voice onset time. In addition, an application called VocaLog, provides feedback regarding only volume level. This sensory biofeedback can be used to remind the wearer of their voice use during voice treatment. This was also one idea of smart clothing uses in our workshop.

In the workshop, participants discussed giving and receiving feedback and its importance in all speech therapy rehabilitation. The participants' ideated feedback could be visual, auditory, or haptic. Participants suggested that smart clothing could collect and give feedback about a client's independent training, and its amount and quality. With feedback it is possible to motivate and activate clients. Feedback may help the clients realize their rehabilitation progress more accurately and increase awareness of their own habits, for example, in voice disorders. Feedback may increase the patient's motivation and activity, and thus rehabilitation might be more effective [42], [22]. Reference [22] reported that different types of technology-based information systems can collect large amounts of information and transmit them to a speech therapist. In this way, the speech therapist could use technology to obtain important information about, for example, the amount and quality of the client's independent training [43]. In addition, the data collected could be used to aid in clinical decision-making, and thus decisions would be based on objective measured data and therefore be more patient-centered and targeted [44].

B. Ways of using and operating smart clothing

The participants voted continuous registration of voice and swallowing functions as the best ideas on how to utilize smart clothing in adult speech therapy. The most popular garment named in the ideation workshop was a shirt with a high collar or just a collar. These garments were seen as optimal to evaluate swallowing and voice production, since collars are close to the neck. In this context, smart clothing was seen to function like a surface EMG (electromyography), which assesses muscle function by recording muscle activity. Participants highlighted the idea in which smart clothing would be used to customize exercises individually based on the collected data. Thus, clients could receive exercises that are optimal for them according to their own personal pace of progress, saving speech therapists' resources [23], [24]. The participants ideated that body movements, gestures and touch could be used to control smart clothing.

V. Conclusion

We organized the ideation workshop with four speech therapists, purpose of which was to explore the visions of speech therapists on how smart clothing could be utilized in adult speech therapy. Patients with dysphagia and voice disorders and measurement of physiological phenomena related to swallowing and voice production were seen as potential applications of smart clothing. Physiological data could be collected via smart collar, and data could be used to give feedback to the user, to customize training and to assess rehabilitation objectively. Body movements, gestures and touch were seen as an easy way to control smart clothing. Thus, smart clothing could be a suitable user interface for smartphone, tablet, or computer for individuals with cognitive and motor disabilities. Smart clothing could take advantage of any voluntary movement in any part of the body.

To conclude, it is important to keep in mind that the suitability of technology-assisted rehabilitation must always be considered case-by-case, since technology skills vary between individuals, especially in older populations [45], [46]. A significant future challenge is to resolve how people with cognitive and motor disabilities could use technology as independently as possible [24]. Research should address how to make devices easy to use and how to personalize devices based on users' abilities. For example, individuals with aphasia, may have difficulties using technology because of impaired ability to understand and produce spoken or written language and partial or total loss of function of a body part, usually the limbs [47], [48]. RFID-based smart clothing could provide a solution to these usage challenges with its simple and easy-to-use technology, as the RFID technology utilized by smart clothing is maintenance-free and could be controlled, for example, by body movements, gestures, and touch [32 – 34].

References

[1] R. Body and L. McAllister, *Ethics in speech and language therapy*, Wiley, 2009.

[2] M. Laberge, "Language disorders", in J. L. Longe *The Gale Encyclopedia of Nursing and Allied Health* (4th ed.) s. 2019–2023, 2018. Gale. Available https://link.gale.com/apps/doc/CX3662600004/GVRL?u=tampere&sid=GVRL&xid=1caed115

[3] M. Laberge, "Speech disorders", in J. L. Longe *The Gale Encyclopedia of Nursing and Allied Health* (4th ed.) pp. 3299–3303, 2018. Gale. Available https://link.gale.com/apps/doc/CX3662600004/GVRL?u=tampere&sid=GVRL&xid=1caed115

[4] L.L. LaPointe, B. E. Murdoch, and J.A.G Stierwalt, "The neurologic basis of speech and language" in *Brain-Based Communication Disorders*. San Diego: Plural Publishing, 2010. Print, pp 1–38.

[5] J. Stemple, N. Roy, and B. Klaben, "Etiologies of voice disorders" in *Clinical voice pathology: theory and management* (Sixth edition). San Diego: Plural Publishing Inc. 2018, pp. 63–82.

[6] C. Sapienza, and B. Hoffman Ruddy, "Vocal pathology", in *Voice disorders* (Third edition). San Diego: Plural Publishing Inc. 2018, pp. 141–194.

[7] J. Stemple, N. Roy, and B. Klaben, "Instrumental measurement of voice" in *Clinical voice pathology: theory and management* (Sixth edition). San Diego: Plural Publishing, 2018, pp. 177–236.

[8] C. Sapienza and B. Hoffman Ruddy, "Vocal rehabilitation", in *Voice disorders* (Third edition). San Diego: Plural Publishing Inc. 2018, pp. 225–280.

[9] J. Gustafsson, S. Ternström, M. Södersten, and E. Schalling, "Motor-learning-based adjustment of ambulatory feedback on vocal loudness for patients with Parkinson's disease", *Journal of Voice*, vol. 30, no. 4, pp. 407–415, July 2015

[10] H. Abusnieneh and M. Saleh, "Registered nurse's competency to screen dysphagia among stroke patients: Literature review", *The Open Nursing Journal*, vol. 12, pp. 184–194, August 2018

[11] S. Hines, K. Kynoch, and J. Munday, "Nursing interventions for identifying and managing acute dysphagia are effective for improving patient outcomes: A systematic review update", *The Journal of Neuroscience Nursing*, vol. 48, no. 4, pp. 215–223, August 2016.

[12] I. Ilott et al., "Evaluating a novel approach to enhancing dysphagia management: workplace-based, blended e-learning", *Journal of Clinical Nursing*, vol 23, no. 9–10, pp. 1354–1364, May 2014.

[13] M. Khoja, "Registered nurses' knowledge and care practices regarding patients with dysphagia in Saudi Arabia", *International Journal of Health Care Quality Assurance*, vol. 31, no. 8, pp. 896–909, October 2018.

[14] J. Logemann, "Introduction: Defenitions and basic principles evaluation and treatment of swallowing disorders" in *Evaluation and treatment of swallowing disorders*, 2nd ed, Pro-ed. 1998, pp. 1–11.

[15] KC. See, SY. Peng, J. Phua, CL. Sum, and J. Concepcion, "Nurse-performed screening for postextubation dysphagia: a retrospective cohort study in critically ill medical patients", *Crit Care*, vol. 20, no. 1, pp. 326, October 2016.

[16] N. Yagi et al., "A noninvasive swallowing measurement system using a combination of respiratory flow, swallowing sound, and laryngeal motion", *Medical & Biological Engineering & Computing*, vol. 55, no. 6, pp. 1001–1017, September 2017.

[17] M. Kim et al., "Flexible submental sensor patch with remote monitoring controls for management of oropharyngeal swallowing disorders", *Science Advances*, vol. 5, no. 12, pp. 3210, December 2019.

[18] E. Sazonov et al., "Non-invasive monitoring of chewing and swallowing for objective quantification of ingestive behavior", *Physiological Measurement*, vol. 29, no. 5, pp. 525–541, April 2008.

[19] D. Jayatilake et al., "Smartphone-based real-time assessment of swallowing ability from the swallowing sound," in *IEEE Journal of Translational Engineering in Health and Medicine*, vol. 3, pp. 1–10, 2015, November 2015.

[20] R. Palmer et al., "Computer therapy compared with usual care for people with long-standing aphasia poststroke: a pilot randomized controlled trial", *Stroke*, vol. 24, no. 7, pp. 1904–1911, July 2012.

[21] R. J. Wenke et al., "Is more intensive better? Client and service provider outcomes for intensive versus standard therapy schedules for

functional voice disorders", *Journal of Voice*, vol. 28, no. 5, pp. 652.e31–652.e43, June 2014.

[22] C. A. Des Roches and S. Kiran, "Technology-based rehabilitation to improve communication after acquired brain injury", *Frontiers in Neuroscience*, vol 11, pp. 382–382, July 2017.

[23] Y. Elsahar, S. Hu, K. Bouazza-Marouf, D. Kerr, and A. Mansor, "Augmentative and alternative communication (AAC) Advances: A Review of Configurations for Individuals with a Speech Disability", *Sensors (Basel)*, vol 19, no. 8, pp.1911, April 2019.

[24] S. Gilroy, J. McCleery, and G. Leader, "Systematic review of methods for teaching social and communicative behavior with high-tech augmentative and alternative communication modalities", *Review Journal of Autism and Developmental Disorders, vol. 4*, no.4, pp. 307–320, August 2017.

[25] A. Vecchiattini et al., "A WSN HMI glove for safety critical applications in hazardous areas," in *IECON Annual Conference of the IEEE Industrial Electronics Society*, Beijing, China, November 2017, pp. 8464–8470. New York: IEEE.

[26] P. Mátételki et al., "An assistive interpreter tool using glove-based hand gesture recognition," in *IEEE Canada International Humanitarian Technology Conference - (IHTC)*, Montreal, QC, Canada, June 2014, pp. 1–5. New York: IEEE.

[27] N. Navaitthiporn et al., "Intelligent glove for sign language communication," *in 12th Biomedical Engineering International Conference (BMEiCON)*, Ubon Ratchathani, Thailand, November 2019, pp. 1-4. New York: IEEE.

[28] Z. Zhou et al., "Sign-to-speech translation using machine-learning-assisted stretchable sensor arrays", *Nature Electronics*, vol. 3, pp. 571–578, May 2020.

[29] R. Saxena et al., "Braille hand glove - A real time translation and communication device," in *International Conference on Computing for Sustainable Global Development (INDIACom)*, New Delhi, India, 2016, pp. 1714–1718.

[30] Y. Yunusova et al., "Game-based augmented visual feedback for enlarging speech movements in Parkinson's disease," *J. Speech Lang. Hear. Res.*, vol. 60, no. 6S, pp. 1818–1825, June 2017.

[31] J. W. Folkins, T. Brackenbury, M. Krause, and A. Haviland, "Enhancing the therapy experience using principles of video game design", *American journal of speech- language pathology,* vol. 25, no. 1, pp. 111–121, February 2016.

[32] H. He et al., "ClothFace: a batteryless RFID-based textile platform for handwriting recognition", *Sensors (Basel, Switzerland),* vol. 20 no. 17, pp. 4878–, August 2020.

[33] A. Mehmood et al., "Body movement-based controlling through passive RFID integrated into clothing", *IEEE Journal of Radio Frequency Identification, vol. 4, nro. 4*, pp. 414–419, July 2020.

[34] A. Mehmood et al., "ClothFace: A Passive RFID-Based Human-Technology Interface on a Shirtsleeve", *Advances in Human-Computer Interaction, 2020*, 1–8. August 2020.

[35] S. Amendola, L. Bianchi and G. Marrocco, "Movement detection of human body segments: passive radio-frequency identification and machine-learning technologies", *IEEE Antennas Wirel. Propag. Mag.*, vol. 57, no. 3, pp. 23–37, June 2015.

[36] H. Jin, Z. Yang, S. Kumar, and J. Hong, "Towards wearable everyday body-frame tracking using passive RFIDs", *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies,* vol. 1, no. 4, pp. 1–23, January 2018.

[37] R. Krigslund et al., "A novel technology for motion capture using passive UHF RFID tags", *IEEE Trans. Biomed. Eng.*, vol. 60, no. 5, pp. 1453–1457, May 2013.

[38] P. Hamilton, "The Workshop Book. How to design and lead successful workshops," United Kingdom: Pearson Education, 2016, p. 232.

[39] A. Woolley, C. Chabris, A. Pentland, N. Hashmi, and T. Malone, "Evidence for a collective intelligence factor in the performance of human groups," Science, vol. 330, no. 6004, pp. 686–688. October 2010

[40] V. Braun and V. Clarke, "Using thematic analysis in psychology. Qualitative Research in Psychology", vol. 3, no. 2, pp. 77–101. July 2008.

[41] S. Elo et al., "Qualitative content analysis: A focus on trustworthiness," *SAGE Open*, vol. 4, no. 1, pp. 10, February 2014.

[42] S.K. Bhogal, R. Teasell, N. C. Foley and M. R. Speechley, "Rehabilitation of aphasia: more is better", *Topics in Stroke Rehabil*, vol. *10*, pp. 66–76. February 2015.

[43] S. M. Harnish et al., "Dosing of a cued picture-naming treatment for anomia", *American Journal of Speech-Language Pathology*, vol. 23, no. 2, pp. 285–299, May 2014.

[44] S. Kiran, C.A. Des Roches, I. Balachandran, and E. Ascenso, "Development of an iPad based clinical decisionmaking workflow for individuals with language and cognitive deficits", *Seminars in Speech and Language*, vol. 35, no. 1, pp. 38–50, January 2014.

[45] K. J. Ballard, N. M. Etter, S. Shen, P. Monroe, and C.T. Tan, "Feasibility of automatic speech recognition for providing feedback during tablet-based treatment for apraxia of speech plus aphasia", *American Journal of Speech - Language Pathology*, vol. 28 no. 2, pp. 818–834, July 2019.

[46] A. Sitren and S. Vallila-Rohter, "How well do we use our technology? Examining iPad navigation skills in individuals with aphasia and older adults", *American Journal of Speech-Language Pathology*, vol. 28, no. 4, pp. 1523–1536, September 2019.

[47] C. Brandenburg, L. Worrall, A. D. Rodriguez, and D. Copland, "Mobile computing technology and aphasia: an integrated review of accessibility and potential uses", *Aphasiology*, vol. 27, pp. 444–461, April 2013.

[48] W. van de Sandt-Koenderman," Aphasia rehabilitation and the role of computer technology: Can we keep up with modern times?", *International Journal of Speech-Language Pathology*, vol. 13, no. 1, pp. 21–27, February 2011.