How can digital technology support people with hearing and speech impairment?

Literature Review

**Introduction**

International organisations and national governments recognise and support inclusion of disabled people into all aspects of society as well as their rights to have opportunities on equal basis as non-disabled people. Equal access to education is essential to achieve this parity. The United Nations (UN) Convention on the Rights of Persons with Disabilities (UN CRPD, 2006) promotes inclusive practices for disabled adults and children across all social schemes, including education, employment and social interaction. The UN Convention on the Rights of the Child (UN CRC, 1989) addresses the right of every child to access education and specifically refers to the non-discrimination of children with disabilities. National laws also mandate the inclusion of disabled individuals into society and education. For example, in the United Kingdom (UK), the Equality Act provides a legal frame for the inclusion of people with disabilities in the workplace and in wider society (UK Government, 2010). The Federal government of the United States Individuals with Disabilities Education Act (IDEA) promotes inclusive education and the use of assistive technology devices (ATDs) for children with disabilities (NAEYC, 2009).

Hearing and speech impairment may lead to a delay in children physical and mental development. The term assistive technology defines the equipment, devices and systems that facilitates the execution of daily tasks for persons with special needs. Inclusive education stands for providing an appropriate education environment with specific resources that allow the participation and motivation of children with disabilities, empowering them and removing barriers to learning (Mackenzie, Cologon & Fenech, 2016). The key for a successful inclusive education is to identify and remove the barriers experienced by children and address them using suitable ATDs (Allen & Cowdery, 2012). Positive outcomes of the use of ATDs include the capacity for increasing children’s independence and participation, removing isolation, and advancing learning and developmental potential for students with disabilities (Bowser & Reed, 2012). For children with hearing and speech impairment, pictures, visual schedules, Augmentative Alternative Communication (AAC) devices (such as Go talk or Tobii DynaVox) and Picture Exchange Communication System (PECS) make learning accessible and help them access the curriculum and communicate with teachers and peers.

However, while it is recognised that digital technologies are essential for the development of children with disabilities, their achievement of an appropriate education level and full participation in society, they remain inaccessible for many (Alper & Goggin, 2017). According to the World Health Organization (WHO), only 5-10% of the global population of people with disabilities have access to assistive technology products (WHO, 2022). Opportunities for adults and children with disabilities to access and use assistive technologies differ between different countries, society groups or cultures (UNESCO, 2021; Donner, 2015; Pal, 2015). Barriers for accessing education systems exist on all levels of instruction. The UN reports that in 2021 children with disabilities are 24 per cent less likely to receive early stimulation and responsive care and 49 per cent more likely to never attend school (UN, 2021).

**Review of current research initiatives**

In recent years many initiatives in the research and development of assistive technology for communication have taken place. This research field includes disciplines such as Computational Linguistics, Speech Processing, and Assistive Technology, which have been collaborating with the purpose of improving speech processing, or Text To Speak (TTS) devices for people that rely on augmentative and alternative communication (AAC) needs (McCoy et al.,2013). Advanced speech recognition algorithms have made it easier to implement communication devices for speech impaired people. Current state of the art TTS devices are using neural network based speech synthesis which gives synthesised speech close to human (Ren et al. 2019). In recent years the approach for speech synthesisation in TTS systems has shifted from concatenative and statistical parametric approaches (Wu et al., 2016) to neural network due to a better success rate and speech quality. However, continuous efforts to improve this type of TTS are being performed as neural network TTSs suffer from slow speed or accuracy (i.e. some works are skipped or repeated), one of the most advanced research initiatives in this field is the FastSpeech TTS (Ren et al. 2019). Another current field of research in TTS devices is the need to provide voices that are more appropriate and acceptable. Specially, for users with gradual or partial speech impairment this feature increases the acceptability rate (Creer et al., 2013). Personalised synthetic voices are important for users with speech impairment to keep social interaction and to avoid withdrawal from society. Research projects based on statistical parametric synthesis models are working towards the implementation of speech recordings databases and the generation of personalised synthetic voices from these recordings. These systems fit the needs of people with progressive conditions who may record their voice before their speech has deteriorated. Lastly, a relative new research initiative is the brain-computer interface research that is studying how brain signals can be interpreted by a computer to help speech impaired people communicate (NIDOCD, 2022). The aim is to implant electrodes on the person’s brain that will be able to translate the person’s movements typing words or even their thoughts into synthesized words and sentences.

Speech recognition has been one of the first applications of deep learning algorithms since their introduction (Nassif et al., 2019) and several Automated Speech Recognition (ASR) applications based on deep learning have been successfully developed. For example, the Microsoft Audio Video Indexing Service (MAVIS) application reduces the word error rate (WER) reduced on four major benchmarks by 30% compared to earlier applications (Microsoft, 2008). Several research works have performed systematic evaluations of the efficiency of using deep learning and neural networks in ASR applications (Morgan, 2012; Hinton et al., 2012; Deng et al., 2013; Li et al., 2014). Results suggest that optimal results are obtained with applications that combine neural networks and conventional speech recognition systems based on statistical models, Hidden Markov model (HMM) and Gaussian Mixture Models (GMMs). The solution is to use neural network models for multiple layers of signal pre-processing prior to the statistical models decoding of sentences. The main function of an ASR application is to recognize the content of words and phrases and transform them to a machine understandable language. Developments of neural network-based ASR applications allow additional features like automatic speaker recognition, identification and recognition of a known speaker, emotion recognition, automatic health recognition, age and gender recognition or even spoken language and accent recognition. Current research efforts are concentrating in these features (Byun & Lee, 2021; Dnvsls et al. 2020).

**Current Assistive Technologies**

The National Institute on Deafness and other Communication Disorders (NIDOCD) classifies the assistive devices for people with hearing and speech impairment in three categories: Assistive listening devices (ALDs), Augmentative and alternative communication (AAC) devices and Alerting devices (NIDOCD, 2022). ALDs help improve sound transmission for people with hearing loss. There are different types of ALDs, there are devices especially designed to be used in places where there’s a lot of background noise such as classrooms, theaters, places of worship, and airports and devices designed for personal use in small settings and for one-on-one conversations. Some work independently and others can be used in combination with hearing aids or implants. Devices for large spaces include hearing loop systems, where sounds are amplified by an electromagnetic field and picked up directly by a hearing receiver built in a hearing aid making the sound much clearer and removing as much of the background noise; frequency-modulated (FM) systems, which are often used in classrooms and are based in the same principle as loop systems but use radio signals to transmit amplified sounds, receivers can be tuned to listen to the desired channel; and infrared systems, where a transmitter converts sound into a light signal and sends it to a receiver that is worn by a listener, as infrared signals cannot pass through walls this system is useful for places where competing signals can be a problem, such as classrooms or movie theatres. Lastly, personal ADLs in form of a device with the size of a mobile phone are available for places where the above systems are not available. These devices amplify sounds and reduce background noise for the listener and have the possibility to be directed towards the source of sound to improve the receiving signal.

AAC devices can range from a simple picture board or touch screen to a device that synthesizes speech from text. People with speech difficulties use these devices for communication with the help of pictures or a text display. Text displays can be enhanced with spelling and word prediction that can make the communication faster and easier. Speech generating devices transform text or pictures to speech; to ease communication these devices can have prerecorded common words or sentences. As previously discussed, there is currently a lot of research initiatives in this field. Alerting devices are used to notify about the occurrence of certain events using sound, light, vibrations, or a combination of these techniques. Typically, they are connected to household devices, such as doorbells, telephones, baby alarms, etc. Receivers can be placed around the house or can be portable vibrating pagers that users carry around.

There are plenty of assistive mobile applications specifically designed to support education of young children with learning difficulties that take advantage of the visual, touch-based interfaces of mobile phones and tablets and use sound and text-to-speech to give kids a voice (Common Sense Education, 2022). These mobile applications have been designed to attract young children attention and increase their motivation and participation in classroom, some examples are Speech Journal, Articulation Station, QuestionIt, nawmalEDU, Proloquo2Go or ClaroSpeak. Students with speech disabilities rely on assistive technology for communication in the form of TTS applications. TTS applications commonly used in education include Natural Reader, Kurzweil 3000, Balabolka, SpeakIt, PowerTalk or Select and Talk. However, several research papers (Torrado et al., 2020; Desmond et al., 2018; Cumming & Rodríguez, 2017) show that the key elements to successfully integrate assistive technologies in education are the correct selection of devices according to children’s needs, access to information about the effectiveness of certain applications by teachers and professionals and measurement of the effectiveness case by case. For older hearing-impaired students in secondary school, college or university, lip reading is the technique used for understanding speech but during class they need to write and do other activities that impede them to concentrate on lip reading. Therefore, they rely on assistive technology such as the ALDs described above and the provision of a more visual teaching approach (Budhi Santoso et al., 2020).

**Conclusion**

People with hearing and speech impairments can experience restrictions in their social interactions. Assistive technology enables people with disabilities to live a more productive, independent, dignified, and healthier life and effectively improves their quality of life. It makes possible for them to participate in all aspects of society, from education to work life and social interaction. To maximise the chances of integration in adult life access to education is critical. Thanks to the rapid advances in assistive technology, the use of tools for the academic and personal growth of children with disabilities has become widely available to students, parents, and teachers. “Studies have shown that effective use of assistive technology enables young children with disabilities to bypass their weaknesses because the devices augment children’s strengths to reach their potential” (Tamakloe & Agbenyega, 2017). This approach allows individualization and self-improvement and increase the children motivation. However, to successfully use these tools, it is critical that the professionals in education are aware of the available technologies, develop a plan for their use and monitor the progress of the children.

Finally, the right to equal opportunities for people with disabilities has been internationally recognised and ratified by international organisations and national governments. Yet, across the globe many people who need assistive technology do not have access to it. Currently, assistive products are mainly available to high-income countries, and in many cases, they are not included in health and welfare schemes, making them not accessible to certain groups. Provision and research of these products should be guaranteed by state funding and world-wide delivery systems (WHO, 2018).

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