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TOOLS USED TO TREAT CENTRAL AUDITORY PROCESSING DISORDERS: A CRITICAL ANALYSIS

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TOOLS USED TO TREAT CENTRAL AUDITORY PROCESSING DISORDERS: A CRITICAL ANALYSIS

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The aim of this month's newsletter is to discuss the aural rehabilitation tools currently used in speech therapy clinics for patients with central auditory processing disorder (CAPD). However, before we begin, let us review some of the basic principles.

Central auditory processing (CAP) is an individual's ability to respond appropriately to sound stimuli through accurate processing by the central auditory nervous system, and this in turn relies on innate capacities built up over years of acoustic experience (Pereira, 2004).

Auditory perception skills and language development are closely related. Indeed, central auditory processing, phonological processing, and linguistic processing have been presented as a continuum (Richard, 2013, 2017), so that it is really not possible to separate the influences of cognitive, auditory, and language mechanisms in the processing of a speech signal (Richard, 2012, 2013; Medwetsky, 2011).

If there is a difficulty in processing a sound stimulus, and it cannot be explained by peripheral hearing loss or cognitive impairment, then we are dealing with a central auditory processing disorder.
A diagnosis of CAPD can be obtained by analysing the age-appropriate central auditory system performance. The analysis can be carried out behaviorally using hearing tests that provide information on hearing abilities, or physiologically and electrophysiologically using tests that analyse the integrity of the auditory pathway.

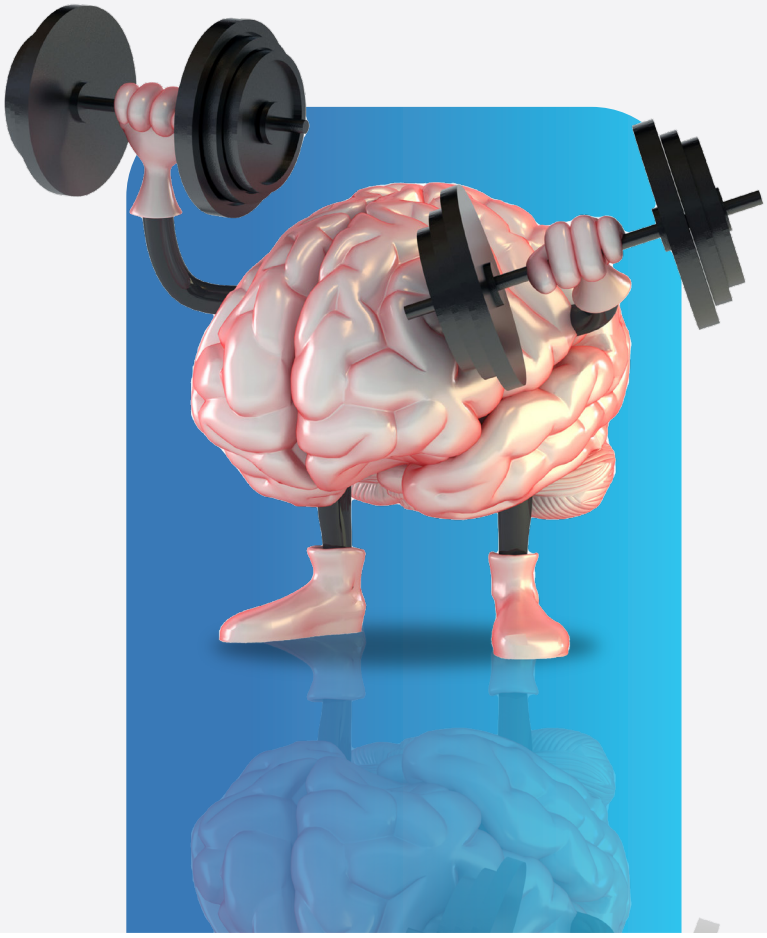
The behavioral assessment of CAP provides information on the neurological processing of sound information received through the ears. Since it is a behavioral assessment, it can be affected by other non-auditory factors, such as attention, memory, language, and executive functions.
Given the complexity of the central auditory nervous system, and the differences that can arise from processing of auditory information by the different structures within it, the treatment of individuals with CAPD depends on the knowledge of the rehabilitation professional, and will involve certain behavioral and environmental modifications brought about by the auditory rehabilitation protocol.

In order for auditory rehabilitation to achieve its desired goal, professionals must base their treatment protocol on scientific evidence.

This article therefore aims to set out the various possibilities for rehabilitating CAPD based on evidence that demonstrates the effectiveness of each method.
The basic principle of rehabilitating CAPD is neural plasticity, which is the brain's ability to mould itself according to the applied stimuli (or in the case of sensory deprivation, a lack of it). Neuroplasticity occurs in various ways throughout life, and in detail involves the modification of neurotransmitters and neuromodulators during growth. It is the basis of development and learning, allowing cognitive strategies to form in the face of environmental challenges (Muskat and Mello, 2012). Plasticity developed through learning promotes changes in behavior, creates synapses, recruits new neurons, and improves neuronal connections (Muskat and Mello, 2012). This plasticity of the nervous system is essential for rehabilitation from CAPD, and draws on its capacity for reorganization and remapping based on experience, i.e. neuronal modification follows from the modification of behaviour. Neural networks are activated by frequent, organised, and intense sound stimuli. With increasing complexity, the level of difficulty of the planned activity is increased, and this is intended to maximise neuroplasticity. Auditory training (AT) is a clinical intervention that aims to manage hearing difficulties and overcome CAPD complaints by stimulating auditory skills. Studies of auditory perceptual learning show that AT is well suited for this. AT programs can be carried out in different age groups and populations. However, it is important to consider the audiological characteristics and cognitive aspects of the individuals who are to receive the intervention. For this reason, some researchers choose to subdivide the terminology into auditory training (AT) and cognitive auditory training (CAT).

In AT, the aim is to improve sound information processing by exercising auditory skills and minimise the symptoms and difficulties resulting from alterations. It consists of a series of challenging tasks designed on the basis of results obtained in a preliminary CAP assessment. In order for an AT program to be effective, it must include certain features such as:

a. The planning of AT activities must include the auditory skills that have been altered;
b. The training task should not replicate the task identified as deficient;
c. The stimuli used in the training task should be varied;
d. Engaging activity with participant involvement;
e. Positive reinforcement of the patient plays an important role in the success of AT;
f. Working with progressive hearing difficulties by means of stimuli and tasks that progress from less challenging to more challenging;
g. Commitment, regularity, and time spent will bring success, so training must be intense, frequent, and stimulating;
h. The level of difficulty must be adjusted to the individual without being tiring or exhausting;
i. Correct score should not be less than 30% and should be below 70%, ensuring that the training is not too easy or not too hard;
j. For young children, the use of interactive games is very effective;
k. The use of acoustic patterns involving the analysis of intensity, frequency, duration, and the type of source generating the sound (human voice, instruments, cars, etc.).
l. In young children, associating auditory stimuli with other sensory inputs (hearing, touch, etc.) has proved useful.



Auditory training programs can be carried out in different age groups and populations. However, close attention needs to be paid to the audiological profiles and cognitive abilities of the individuals targeted for intervention.

There are several formal and informal programs aimed at training auditory skills, and they vary according to the degree of control they have over the presentation of the stimulus and the environment. There are some instruments that have been specifically developed to manage CAPD, but others were initially created with the aim of improving other skills (such as speech and language) and which have subsequently been shown to provide benefits in terms of stimulating the auditory system.

Researchers have suggested that AT can be an extremely effective tool in the intervention of patients with language impairments, learning difficulties, altered temporal or spatial processing, and individuals who use electronic devices (individual sound amplification devices or cochlear implants).

Although the importance of AT programs is undeniable, it is essential that auditory training systems and software meet the criteria of evidence-based healthcare (EBH). EBH refers to the judicious, precise, and careful use of scientific knowledge based on GRADE (Grading of Recommendations, Assessment, Development and Evaluations), which makes it possible to analyse the quality of scientific evidence for each study (Roever et al, 2020).

The quality of the evidence can be divided into four categories:

I. **High:** randomised clinical trial, systematic review, meta-analysis;
II. **Moderate:** randomised clinical trial, systematic review, meta-analysis with conduction problems;
III. **Low:** observational study (cohort study, case-control study);
IV. **Very low:** any other evidence (case series).

For a better understanding of these criteria, an explanatory table of the degrees of evidence of studies and methodologies is shown in Chart

Chart 1: Criteria for classifying levels of evidence and strength of recommendations, according to GRADE criteria

RECOMMENDATION GRADE	STRONG RECOMMENDATION	MODERATE RECOMMENDATION	WEAK RECOMMENDATION	NEGATIVE RECOMMENDATION
Conclusion of evidence	Benefits stronger than risk	Benefits greater than risks	Benefits equal to risk	"We can suggest" "Can be considered"
High Level of evidence	Strong recommendation based on high level of evidence	Moderate recommendation based on high level of Evidence	Weak recommendation based on high level of evidence	No recommendation based on high level of evidence
Moderate/low level of evidence	Strong recommendation based on moderate/ low level of evidence	Moderate recommendation based on moderate/ low level of evidence	Weak recommendation based on high level of evidence	No recommendation based on moderate/ low level of evidence
Very low level of evidence	Strong recommendation based on expert opinion	Moderate recommendation based on moderate/ low level of evidence	Weak recommendation based on moderate/ low evidence Level	No recommendation based on very low evidence Level
Report of recommendations	"We recommend" "We should" "It is recommended/ indicated/helpful/ effective"	"We suggest" "It's probably recommended" "Can be useful or effective"	Weak recommendation based on moderate/ low evidence Level	"We do not recommend" "It is not useful/effective"

Materials for auditory training are available in booklets and different types of software. Computerised systems have advantages due to the possibility of multisensory stimulation. Below we present some of the systems available as well as the existence (or non-existence) of evidence to support each instrument.

Auditory training systems

a. **Afinando o cérebro/Pro Brain:** developed with the aim of stimulating auditory skills. Initially, the activities were made available to patients via CDs and are now available on an online platform with numerous activities for different audiences and age groups. The 'Tuning the Brain' website is a platform that stimulates communication, memory, and attention skills with interactive and educational games. The system has various activities that stimulate different aspects of communication and auditory processing in a fun and entertaining way. There is also a simple auditory processing assessment system. On the website it is possible to access different studies that have been published in national and international peer-reviewed scientific journals (Donadon et al, 2019; Souza et al, 2018; Carvalho et al, 2018). **The system uses verbal and non-verbal stimuli for Brazilian Portuguese**.

b. **Angel Sound:** is an interactive auditory assessment and training program. The aim of this system is to train people in the perception and discrimination of verbal and non-verbal sounds. The program has a series of individual modules (basic, voice recognition, melodic contour identification, music, and others) that work with different aspects of auditory processing. The level of difficulty is automatically adjusted to match the person's developing auditory skills. The program provides audiovisual feedback and can be carried out at home. According to the developer,

the system complements clinical rehabilitation work. There are several scientific studies that have used its methodology (Cheng et al, 2018; Yu et al, 2018; Fu et al, 2015; Zhang et al, 2012; Oba et al, 2013). **The system uses verbal and non-verbal stimuli in English**.

c. **Auditory Rehabilitation for Interaural Assymetry (ARIA):** developed by Prof. Débora Moncrief, University of Memphis. This program aims to treat amblyaudia through repetitive dichotic auditory training. The program is suggested to be applied in four 60-minute sessions. Studies have shown that auditory training with the ARIA system led to significant gains in dichotic listening test scores in patients diagnosed with CAPD, especially those diagnosed with amblyaudia. The patients were followed up after 12 months of auditory training and the improvements observed were maintained. In addition, improvements were observed in the ability to process speech sounds and in binaural integration skills (Moncrieff et al, 2017). A recent study hypothesised that pre- and post-treatment severity ratings are predictors of improvements in dichotic listening tests after training with the ARIA system (White and Moncrieff, 2023). **The system uses verbal stimuli in English**.

d. **aTune:** designed to improve the perception of musical pitch in cochlear implant (CI) users. The program offers a comprehensive range of exercises covering phonetic discrimination, spatial perception, auditory memory, and listening comprehension. The program uses a platform with interactive features and the possibility of monitoring progress on an individual basis, with instant feedback on performance, allowing for adjustments to the program. aTune is suitable for CI users of all ages and with different levels of hearing experience, from newly implanted users – where it can help adapt to the CI and speed up hearing rehabilitation – to users with specific difficulties such as phonetic discrimination or listening comprehension in noisy environments. **The system uses verbal and non-verbal stimuli in English**.

e. **Berard Auditory Integration:** based on the premise that sound, in the form of music, can help reorganise brain processing capacities. The training must be carried out by a designated instructor and use a specific device. Training can be carried out in person or remotely. The author has applied the technique to a variety of disorders such as autism, depression, learning

difficulties, and hyperactivity. The technique involves 10 hours of listening, using headphones, to electronically modified music for two 30-minute sessions over 10 days. The program's website presents some studies, but they were published without prior expert analysis. **The system uses verbal and non-verbal stimuli in English**.

f. **Brain Fitness Program:** the program consists of six interrelated training exercises that together cover the acoustic organisation of speech. The exercises include temporal ordering, discrimination, short-term memory, instruction comprehension, and narrative memory tasks. Each exercise employs a combination of acoustically controlled stimuli, with the possibility of adapting the tasks (Mahncke et al, 2006). Studies have shown, in older adults, a general improvement in untrained tests of memory, attention, and processing speed, as well as improved neural timing and speech perception in noise (Anderson et al, 2013; Smith et al, 2009). **The system uses verbal and non-verbal stimuli in English**.

g. **Constraint Induced Auditory Therapy (CIAT):** is a dichotic auditory training program based on Dichotic Interaural Intensity Difference training developed by Hurley and Davis of the LSU Health Sciences Center. It is designed for people with specific hearing deficits in dichotic listening tests (including children with dyslexia, people with hypersensitivity to noise, adults with aphasia or anyone interested in improving their hearing ability). It uses dichotic stimuli which can improve the attention of the poorer performing ear and improve performance in noisy environments. No scientific studies have been found using this methodology. **The system uses verbal and non-verbal stimuli in English**.

h. **Earobics:** An educational software program for teaching auditory and phonological awareness skills. This system stimulates different skills and can be applied at different levels of difficulty. However, the software is no longer available for access. **The system used verbal and non-verbal stimuli in English**.

i. **Fast ForWord:** developed to address language and literacy difficulties in children. The program uses acoustically modified speech that makes it possible to analyse what has gone wrong to cause rapid changes in temporal processing skills. Studies published in scientific journals with double-blind peer review (Merzenich et al, 1988, 1996; Miller and Tallal, 1995; Gaab et al, 2007; Temple et al, 2003) have shown that intensive listening clarifies the distribution of neuronal representations of the acoustic structure of speech with positive and

far-reaching neurobehavioral consequences. **The system uses verbal and non-verbal stimuli in English**.

j. **HearBuilder Auditory Memory:** is an online training program that allows the training of different types of skills such as auditory memory, auditory closure, auditory comprehension, and phonological awareness using a bottom-up approach. The system also offers a noise option to improve figure–ground listening skills. According to Richburg et al (2017), who used the methodology associated with other techniques on one individual, improvements were observed in specific therapeutic activities after about 4 months of intervention. However, no improvements were observed in classroom performance or reading skills after one year of the intervention process. **The system uses verbal and non-verbal stimuli in English**.

k. **Insane Earplane (IE) and Zoo Caper Skyscraper (ZCS):** developed to address a range of auditory processing skills. The IE system was designed to work on four areas (lateralisation, interaural differences in time and intensity, frequency patterns, and duration), while the ZCS system was developed to gradually improve dichotic listening skills. Studies have demonstrated the effectiveness of ZCS and IE after therapeutic intervention, with an improvement in sensitivity to lateralisation and analysis of tonal patterns being observed in IE, while in ZCS an improvement in dichotic listening was identified (Barker and Hicks, 2020). **The system uses verbal and non-verbal stimuli in English**.

l. **Johansen Individualized Auditory Stimulation:** is a musical hearing training program that uses custom recordings for each individual for about 10 to 15 minutes using headphones. Training usually takes place over 8 to 12 months. Dyslexic subjects between the ages of 13 and 17 were divided into three groups: an intervention group for dyslexics, a control group for dyslexics, and a control group for non-dyslexics. The intervention group listened individually, for 10 minutes daily, for 15 to 18 months, to computer-generated music CDs customised according to the results of their central hearing processing tests. Improvements in reading (decoding) and spelling skills in the intervention group for dyslexics support a link between basic sensory perception skills and language-related skills at the phonological level (Zwart, 2021). **The system uses verbal and non-verbal stimuli in English**.

m. **Listening and Communication Enhancement (LACE):** is a hearing training and hearing rehabilitation software developed by audiologists and experts in the area of hearing loss. LACE helps people with hearing loss or difficulty in conversing in noisy environments by improving key hearing skills. The system is based on adaptive training. Sweeton (2004) conducted a pilot project with the system and suggested that hearing skills can be improved with practice and feedback. The LACE therapy therefore aims to improve hearing skills and communication strategies. **The system uses verbal and non-verbal stimuli in English**.

n. **LiSN-S/ LiSN & Learn:** is a hearing training software developed and validated for

the treatment of children with spatial processing disorder. This disorder is characterised by a difficulty in binaural hearing in environments where there is competing sound information. Individuals with this disorder have difficulty distinguishing a target speaker in the presence of other sounds. The systems were developed by the National Acoustic Laboratories and research has been published in peer-reviewed journals (Cameron et al, 2015; Cameron et al, 2012; Cameron & Dillon, 2010, 2011). **The system uses verbal and non-verbal stimuli in English.**

o. **The Listening Program (TLP):** This methodology is based on the idea that music has a role in improving mental, physical, and emotional health. The music is acoustically modified and is intended to strengthen the neurological pathways, resulting in a better ability to learn, communicate, and process information. Butler et al (2020) noted improvements from using the methodology, but the study did not use a control group. **The system uses verbal and non-verbal stimuli in English**.

p. **Memory Booster:** is a computerised training program that teaches different memory strategies for children. A short animated story is presented to the patient and, subsequently, other concepts are presented that need to be remembered. The program is tailored to the needs of each child. In a study by Cameron et al (2015), training was conducted 15–20 minutes a day for 5 days a week over 2 months; in addition, children received a frequency modulated (FM) system. The results showed improvements in post-training scores in some of the tests. **The system uses verbal and non-verbal stimuli in English**.

q. **Método SENA (Sistema de estimulação NeuroAuditiva):** developed to enhance the phonoaudiological therapies of learning, language, attention and concentration disorders, and in activities related to sound interpretation. An improvement in central hearing function would give an improvement in threshold linearity, and symmetry and fusion between the ears. On the site there is the indication of some scientific studies related to hearing and neuroauditive stimulation, but without specific results. One study that used the methodology (PhD thesis, Viacelli, 2019), concluded that the therapeutic procedures were effective; however, the results should be interpreted with caution as there is a need for additional research. **The system uses verbal and non-verbal stimuli in Spanish and Brazilian Portuguese**.

r. **Samonas Sound Therapy (SST):** is a music hearing training software that uses special headphones to transmit electronically modified music. The aim is to improve hearing skills through a period of repeated listening which, according to the creators, would be useful for children with autism or hearing processing disorders. The duration and frequency of treatment for each patient is at the discretion of the therapist and there are no specific guidelines. There is one study conducted on a small

number of patients that concluded that SST could be a useful tool for severe cases of autism spectrum disorder specifically related to social involvement. (PhD thesis, Pitkola, 2016). Further research is needed to confirm whether the Samonas methodology improves the symptoms of ASD and ASD in children. **The system uses non-verbal stimuli in English**.

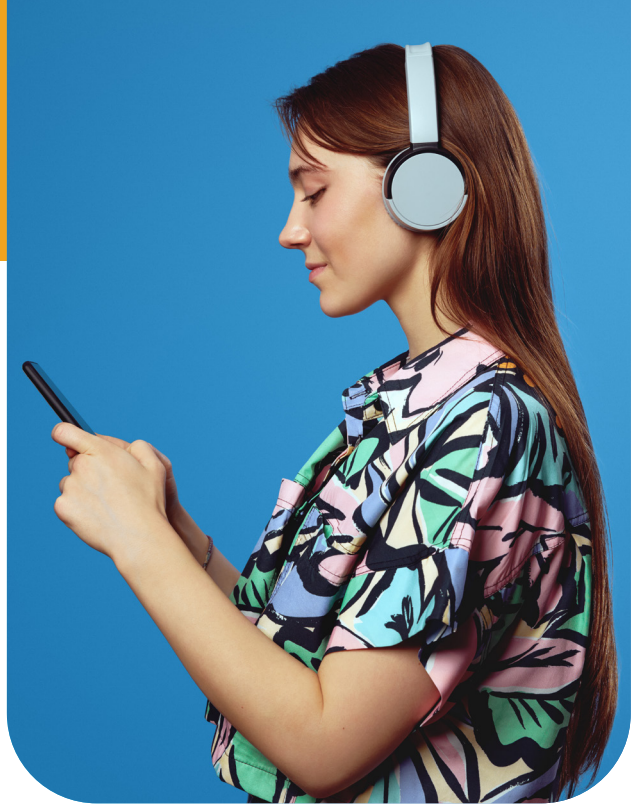
s. **Sound Storm:** It was originally developed by National Acoustic Laboratories (NAL) and Hearing Australia and was subsequently acquired by a private company. Its aim is to remedy spatial hearing loss in school-age children and some scientific studies have proven its effectiveness (Cameron & Dillon, 2011; Cameron et al, 2012; Kiri & Harkusb, 2020). **The system uses verbal and non-verbal stimuli in English language**.

t. **Stimulator of the Polymodal Sensory Perception by Skarzynski (SPPS-S):** is an intervention program that encompasses various groups of disorders that are associated with disturbances to hearing processing (delayed speech development, dyslalia, hearing attention disorders; difficulty reading and writing; dysphagia and voice disturbances). The combination of hearing stimulation with psychological training is an innovative element of the method. The intervention process averages 10 days, with daily sessions of 2–3 hours daily and varied activities through multimedia and psycho-educational games. Papers have shown that the methodology is effective both in the clinic and the home, with post-intervention tests showing improvements in different hearing skills (Skarzynski et al, 2023). **The system uses**

verbal and non-verbal stimuli in Polish, although work is under way in other languages (Spanish, Brazilian Portuguese, and Russian).

u. **Tomatis Approach:** The principle of the method is that any change in the way an acoustic message is received and analysed will affect the way the message is reproduced. By improving phonological and linguistic awareness, the method attempts to understand, analyse, and interpret the basic sounds of language. The training programs are individualised with variability in the duration of the intervention and intervals between treatment blocks. El-Tellawy et al (2022) conducted a study combining Tomatis sound therapy and hyperbaric oxygen therapy that appeared to prove useful in children with ASD. There is also an integrative review (Tomic, 2020) of the effectiveness of the method in children with ASD. There are also some dissertations that have dealt with the topic and are available for reading on the program's website. **The system uses verbal and non-verbal stimuli in English**.

v. **WM training software Cogmed:** is a program developed with the aim of improving attention and consequently working memory. This system has been shown to be effective in improving cognition, reflected in improvements in patient health and education.



Improvements in working memory and inhibitory control have been shown to be important in improving a person's other skills and abilities (Aksayli, 2019; Berger et al, 2020), although there are some contradictory studies. For example, some work has shown improvements in how well children with cochlear implants can repeat sentences (Kronenberger et al, 2012), while other studies failed to show any benefits from training in the day-to-day communication abilities of adults with hearing aids. (Henshaw et al, 2022). **The system uses verbal and non-verbal stimuli in English**.

Of the English language programs mentioned, the AAA (2010) and other leading professional associations representing audiology and pediatrics, do not support the Berard Auditory Integration, the Tomatis Approach, and the Listening Program due to lack of evidence demonstrating effectiveness, their questionable scientific foundations, poorly executed research projects, the potential to cause damage, lack of accuracy, and no acoustic controls (e.g. excessive levels of noise) (ASHA, 1994, 2004; Corbett, et al, 2007; Hall & Case-Smith, 2007; Sinha, et al, 2006). In Brazilian Portuguese, the SENA BRASIL method was investigated by Viacelli (2019) who also associated it with two other training techniques: formal hearing training (also referred to as acoustically controlled) and visomotor training. Viacelli concluded that the therapeutic procedures were effective; however, the results must be interpreted cautiously and there is a need for further research. There was no double-blind evaluation and the work was not published in high-profile journals with peer review. No other studies have used this analysis method. We must conclude that so far there is no robust scientific proof of effectiveness.

According to Chermak et al (2007), computer-assisted programs have many advantages, including an engaging format, multisensory stimulation, feedback and reinforcement and, most importantly, the opportunity for intensive, adaptive, and therefore efficient training. With technological development, new programs focusing on sound therapy and hearing training will be developed and enhanced. However, it is important that health professionals are aware of the advantages and limitations of each method. Finally, it is important that existing methodologies continue to be carefully evaluated so that their evidence quality can be strengthened.

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