PALS0003 Rehabilitation of Acquired Neurogenic Communication Difficulties

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Describe the factors that may affect the speech comprehension abilities of Yazid, a 68-year-old man who had a left-sided CVA eight months ago. He reports difficulties when there are several people speaking at once, or if there is too much background noise. Compare, contrast, and critically evaluate two therapy approaches that might be used to treat his auditory comprehension problems.

A Critical Evaluation of two Auditory Training Programs in Improving Speech Comprehension in the Presence of Competing Sounds

Introduction

Yazid, a 68-year-old man, had a Cerebrovascular accident (CVA), which is more commonly known as stroke on his left hemisphere 8 months ago. He found it difficult to process auditory speech sounds in both energetic and informational masking noisy environments after the stroke. This essay will first discuss both internal and external factors that may affect the speech comprehension ability of Yazid combined with previous literature in the introduction part. Then this essay will make a comparison of the effectiveness of two suitable therapy approaches designed for auditory rehabilitation.

On the one hand, the internal physical conditions of Yazid will affect his speech comprehension ability. First of all, given that Yazid is 68 years old, he might be influenced by presbycusis, an age-related hearing loss even before his stroke. Presbycusis results from a loss of hair cells and bilateral degeneration of the cochlea and associated structures of the inner ear, and it is quite common among people over age 65 (Gates & Mills, 2005). Meanwhile, possible pre-existing hearing disorders or otologic problems, as well as previous occupational noise exposure should also be taken into consideration. Pre-stroke environmental exposure and living styles (eg. smoking) may have a negative influence on Yazid's hearing (Mizoue et al., 2003; Morata et al., 1993).

Secondly, CVA-caused neurological disorder can be a major contributor to Yazid's degraded speech comprehension ability. Sometimes, peripheral hearing or otologic problems will occur along with the neurological event (Häusler et al., 2000). Anatomically, the hearing process requires our ears to convert sound energy into neural signals that will be then transmitted to the auditory cortex and go through a series of processing to get the information those signals contain (Griffiths et al., 2010). However, when abnormalities like ischemic or hemorrhagic stroke happen in the auditory neural pathway, auditory dysfunctions may occur. Previous studies have indicated that the auditory nerve is especially sensitive and vulnerable to stroke impairment (Bamiou, 2015). For example, bilateral damage to the primary auditory cortex may lead to cortical deafness, though it is a relatively rare form of sensorineural hearing loss (Maffei et al., 2017). Unilateral or bilateral hearing impairment, a significant increase in pure tone thresholds, as well as poor performance in speech discrimination tests can all be common complications of cortical or subcortical temporal lobe lesions (Kitamura & Berreby, 1983).

Thirdly, since speech perception entails complex cognitive mechanisms, CVA-caused deficits in cognitive resources (Murray & Lopez, 1996) may also lead to increasing difficulty in speech comprehension in noisy environments. An interactive bidirectional processing system proposes that the bottom-up and top-down processes combine to support speech perception (Davis & Johnsrude, 2007). The top-down information flow means that individual higher-level cognitive resources reinforce the acoustic signal and better facilitate speech comprehension. Also, the ease of language understanding model (ELU) describes the involvement of working memory in mapping the speech signal to phonological representation and the attentional control in inhibiting distractors in noisy environments (Herrmann & Johnsrude, 2020; Rönnberg et al., 2013). Fitzhugh et al. (2021) performed an empirical study using ELU model and found that following a left hemisphere stroke, speech comprehension ability in noisy or multispeaker environments may deteriorate due to deficits in working memory and attentional control when controlling the age and hearing threshold.

On the other hand, external factors may affect Yazid's speech comprehension as well. Speech comprehension in background noise is more difficult even for neurotypicals compared to that in optimal listening conditions (Schneider et al., 2007). But identifying one sound from the presence of various competing sounds is a significant binaural function (Häusler & Levine, 2000). For people after stroke, one frequently reported poststroke auditory deficit is the increasing difficulty in comprehending speech in background noise (Bamiou et al., 2012; Rankin et al., 2014), though they are often neglected in real life due to the lack of tests and self-report. Studies investigating both auditory processing of single words (Raymer et al., 2019) and sentences (Villard & Kidd, 2019) with the presence of competing sounds were done and they found that people with stroke (with and without aphasia) have greater difficulty comprehending speech in noisy environments compared to neurotypical individuals. Notably, these reported less severe forms of auditory disorders are not found to be related to age, and they may happen even when the pure-tone audiometry and speech discrimination ability are normal (Bamiou et al., 2012; Raymer et al., 2019; Rey et al., 2007). Meanwhile, people's speech understanding greatly depends on the speaker. Apart from the influence of background noise, previous research found that the speaker's accent, distorted acoustic signals such as accelerated or decelerated speech, sentence length, etc. all significantly influence the listener's comprehension. And patients with cortical or subcortical brain lesions may be more affected by those external factors compared to neurotypical people (Häusler & Levine, 2000).

To sum up, internal factors such as pre-existing age-related hearing loss, stroke-related hearing impairment, as well as deficits in working memory and attention, and external factors like background noise, speaker's accent, speech rate, etc. are all possible factors that contribute to Yazid's speech comprehension difficulty. Additionally, though Yazid has no reported record of aphasia, he needs a systematic assessment of his language abilities since people with aphasia have been shown to have deficits in speech comprehension as well (Rankin et al., 2014). Patients in the chronic phase of stroke tend to have lasting deficits that bring great inconvenience to their daily life. Therefore, a more detailed assessment of hearing function and aphasia test so as to inform further rehabilitation plan might be of great benefit.

Computerized Auditory Training for Speech-in-Noise comprehension

Auditory training has gained growing attention in improving speech comprehension ability in background noise in recent years. Based on the nature of neuroplasticity, the main principle of auditory training is to enhance people's auditory skills and ability to respond to new auditory patterns by facilitating cortical reorganization of the auditory nervous system (Neuman, 2005). Though the brain is most plastic in childhood, evidence indicates that neuroplasticity is a lifelong capability of the brain (Anderson et al., 2013). Also, with the development of computer sciences, computerized auditory training (CAT) represents a convenient, low-risk, and low-cost approach to improving auditory ability even at home. The only concern is that peer-reviewed evidence for some of the auditory training programs is still quite limited, therefore the efficacy of those programs requires further evaluation. The following is an introduction to two relatively better-known programs, *Listening and Communication Enhancement* (LACE) and *Seeing and Hearing Speech* (SHS), that might be suitable to alleviate Yazid's hearing problems. These two programs are currently commercially available and tested to be efficient in improving comprehension ability in previous studies.

LACE is a home-based, interactive adaptive computer program designed to train the brain to better cope with speech comprehension in challenging listening situations (Sweetow & Sabes, 2007). According to the LACE website (Neurotone, Inc., 2022), the major four types of training situations are picking out speech in noisy environments, speech comprehension in the presence of competing speakers, understanding fast talkers (rapid speech), and cognitive skills training to better fill in the target word. Users are required to repeat the sentences played in the task. The difficulty of the tasks in each session will be adjusted according to the user's response. Visual feedback as well as strategies and techniques that can help users adapt to the challenging communicating environment will be presented on the screen after each task. The training program consists of 20 training sessions, 30 mins for each session, 5 sessions per week, and overall lasts for a period of four weeks. Quick Speech-in-Noise Test (QuirckSIN) is used to examine user's training progress.

SHS (Sensimetrics, Inc., 2021) is designed to provide self-study courses for people with impaired hearing and improve their speech comprehension ability by training them to utilize both auditory and visual cues during conversation. There are mainly four sections in the program with increasing difficulty. Users start by learning to identify different vowels grouped by visual features such as rounded lip vowels, spread lip vowels, and relaxed lip vowels. Then they progress to identify phonemes with similar consonant comparisons, such as bilabial consonants /b/, /p/, and /m/. Also, they will be trained to identify word stress and intonation. Finally, they will learn to understand common phrases and sentences under different topics that are frequently used in everyday communication. Users need to complete a given lesson with over 70 % accuracy rate to progress to the next level of learning. All tasks are presented with both auditory and visual cues. Users can adjust the volume of the background noise, speed of the speech, and choose to turn on or turn off the video of the speaker according to their preference.

Comparison and Evaluation of LACE and SHS

Both LACE and SHS are computer-based auditory training approaches that share the same purpose of improving the speech comprehension ability of people with hearing impairment. This part of the essay will compare and evaluate the two approaches from two aspects, the protocols of the two programs, and training efficacy in empirical experiments.

LACE AND *SHS* PROTOCOL COMPARISON

For the training protocols, first of all, the two programs have different forms of training materials. SHS presents the users with both auditory and visual cues, while LACE focuses only on auditory cues. Visual stimuli can influence auditory perception (eg. McGurk effect). Previous studies have proved that speech intelligibility is enhanced when the listener can perceive visual information of the speaker at the same time in both optimal listening and noisy conditions (Arnold & Hill, 2001; Bernstein et al., 2004; Grant, 2001). Meanwhile, the motor theory of speech perception implies that our perception of speech sounds relies on recognizing the gestures and movement involved in speech production (Liberman & Mattingly, 1985). And Poeppel & Hickok (2004) proposed a dual-stream speech perception model, where the "dual-stream" represents a motor link that allows people to identify and discriminate syllables. Consequently, the visual cues may give the listener more hints on the motor basis of the speech production, thereby promoting the speech perception and facilitating neural connections of such acoustic motor patterns. Compared to LACE, SHS equips users with additional toolkits such as visual cues and lipreading instructions that may help them perform better in challenging communication conditions.

Another difference between the two programs is that SHS uses bottom-up phoneme discrimination and identification training while LACE involves top-down cognition training as well. SHS training follows the progress from phonemes to words and then to phrases and sentences. After the training, the connection between the auditory signal and its phoneme representation will be reinforced. Therefore when it comes to the higher-level speech perception, those trained auditory stimuli will be excited more easily. However, as mentioned in the introduction, cognitive resources like working memory and attentional control are of great importance in speech perception as well. LACE on the other hand includes various types of cognitive training tasks to boost top-down information processing ability other than merely training patients to recognize low-level phonetic features. Those cognitive tasks can enhance the auditory memory and help patients better exploit long-term cognitive resources and short-term memory to fill in the comprehension gaps in the speech.

Additionally, one aspect of the protocol that should also be taken into consideration is that the interactive design should be attractive and user-friendly. Since old or middle-aged people or people with brain lesions consist of a great proportion of the potential auditory training program users, they may be unwilling to learn a self-study program on computer if it is too complicated to get started or not engaging enough. And those factors may also influence people's auditory training outcomes. Both LACE and SHS have succinct interfaces and clear task designs. However, the task forms in SHS are all the same across the entire section, and auditory stimuli are presented in phoneme or single word form for each trial without any context at the beginning of the progress, users can easily get bored halfway through training. Tasks in LACE, on the contrary, contain more semantic information since it uses meaningful sentences as auditory stimuli. Various contexts in different trials make LACE more entertaining and attractive to users. Hence the protocol design of LACE may have higher acceptance adherence among users compared to SHS.

LACE AND *SHS* EFFICACY COMPARISON

Both LACE and SHS website pages claim the training programs to be effective in improving auditory skills and reducing anxiety when communicating. A high-quality study on the effectiveness of LACE has been done by Sweetow & Sabes (2006), nevertheless, study using SHS as auditory training approach is quite limited. Ingvalson et al.(2013) examined SHS effectiveness for postlingually hearing-impaired adults. These two studies will be reviewed and LACE and SHS outcomes in the studies will be evaluated.

Sweetow & Sabes (2006) tested 65 participants with hearing conditions ranging from normal hearing to severe sensorineural hearing loss in a home-based training. Participants had a mean age of 64.7 years old. They were trained with speech sentences in all four types of LACE training situations but on different topics. The training lasted 4 weeks. The experimental group was tested 4 times in total: 2 days before training (baseline), mid of training (2 weeks after the start of training), end of training (post-training), and 4 weeks after the end of training. QuickSIN, Listening Span, Stroop, and Hearing in Noise Test (HINT) are used as performance measurements. The results showed that there were significant improvements ($p < .05$) for all four LACE situations on nearly all outcome measures except for HINT. But non hearing aid users only had significant improvement in speech-in-noise and competing speaker situations. The training improvement can last at least one month post training.

Ingvalson et al.(2013) had a lab-based training on 5 postlingually hearing-impaired adults with a mean age of 71.4 years old. The training focused on vowel and consonant identification in words, phrases, and sentences at different signal-to-noise ratios (SNRs). Participants had a one-hour session per day for four days in total. Participants' performances were measured with SSQ, QuickSIN, and HINT. The results indicated an improvement in speech-in-noise comprehension after the training according to QuickSINS and HINT at +15 dB SNR. No significant effects of SSQ were found. And the improvement can be maintained for at least 4 days.

The two studies showed the effectiveness of both LACE and SHS programs and reported evidence for generalization of the learning outcome to untrained measures. However, there are still several concerns. First, since how different types and degrees of hearing deficits as well as various demographic features might affect the auditory training results still remains unknown, and patients who had lower baseline scores may get greater improvement on outcome measures compared to those with a higher baseline, the training results might not be comparable across studies or even between individuals within the study. Secondly, the sample size of Ingvalson et al.'s study (2013) was too small, and the training period only lasted for a very short period of four days. And since the content of SHS tasks is highly repetitive within sessions, short-term repeated exposure to the training may increase the chance of correct guess rather than real improvement of hearing ability. Therefore, higher quality research is required to further test the effectiveness of SHS.

Conclusion

Though unlike severe hearing dysfunction such as auditory neglect and auditory agnosia, less severe forms of auditory processing deficits like hearing difficulty in challenging communication situations can also have negative influences on patients' regular life. Those forms of hearing deficits may result in social isolation, mental health problems such as depression, lower quality of life, and even an increased odds of poorer stroke recovery (Landi et al., 2006). However, though there are plenty of the possible negative consequences, and reported hearing problems in noisy and competing speaker environments are surprisingly prevalent in the stroke population, literature on post-stroke auditory disorder is still limited compared to other aspects like visual deficits.

Modern technologies have developed personal listening devices to help people deal with challenging listening conditions. For example, frequency modulation (FM) system can pick up the voice signal within inches of the speaker's mouth and transfer them directly to the FM receiver near the listener's ear. It can significantly reduce the interference of background noise. However, such technology requires users to wear complex and visible devices that might be uncomfortable for users psychologically. Additionally, such techniques can only augment the auditory signal rather than truly enhance the user's hearing ability. This essay introduced two auditory training programs LACE and SHS that might be used to improve Yazid's hearing comprehension in the presence of competing sounds, and made a comprehensive comparison and evaluation of the two approaches. The two programs have different protocols in terms of training materials, target training aspects, and task designs. Empirical studies have proved the efficacy of both programs. But the real-world effectiveness of the training still needs further evidence.

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