The Efficacy of Auditory, Visual, and Tactile Feedback in Improving Speech and Intelligibility Skills of People with Severe to Profound Hearing Loss Across Varying Age Levels

Marie Partyka, B.A.

Elmhurst College- Communication Sciences and Disorders

Introduction

Enhanced auditory, tactile, and visual feedback systems have been researched as alternative means of sensory feedback for people with severe to profound hearing loss to improve articulation and intelligibility of speech. The general consensus is that children with hearing loss are on average 20% intelligible, which translates to one word out of every five is understood by the listener. As children enter school, their speech intelligibility is often considered an indication of their abilities, meaning that low intelligibility could result in underestimation of potential. For adults who experience hearing loss, articulation has been shown to dramatically decrease over time, resulting in lowered intelligibility.

Purpose

The purpose of this research is to compare each form of feedback to determine which form of sensory feedback provides the highest levels of efficacy for preschool aged children (3 to 5 years), school aged children (6 to 17 years), and adults (18+ years).

Directions into Velocities of Articulators model (DIVA)

This neural network model of speech motor control and acquisition explains the role of feedback within speech production. When a child learns to babble, they develop a connection between the motor, auditory, and somatosensory information that associates with each sound they produce, called a target map (Guenther & Hickok, 2015). As new sounds are produced, the speech sound map adds a neuron to represent that sound for future productions. This target map is part of the feedforward system and provides articulatory commands of how to produce specific sounds. The feedback system is made up of the error maps, which represent the difference between the expected and actual sensory signals associated with the production of speech sounds (Tourville & Guenther, 2011). As sounds are produced, the error maps compare the signals from the auditory target map to the sounds that were produced to detect differences. If the incoming auditory signal is not within the target region, an excitatory input from the auditory periphery will be sent out, resulting in the activation of the auditory error map cells. Once the auditory error map is activated, corrective motor signals in the model will be activated, which transforms auditory errors into movements that correct these errors. Speakers create these feedforward and feedback systems based on their articulator position maps, which control the fine motor movements of the muscles of the face and vocal tract. People who do not have auditory feedback are unable to form the proper feedforward mappings or have the feedback control needed for articulation refinement.

For people with hearing loss, the traditional auditory feedback from sounds is unavailable due to the diminished or lack of auditory input. Biofeedback devices are being researched as an alternative form of input to develop and maintain the feedforward and feedback systems in order to improve the speech and intelligibility of people with severe to profound hearing loss.

References

Bacsfalvi, P., Bernhardt, B., & Gick, B. (2007). Electropalatography and ultrasound in vowel remediation for adolescents with hearing impairment...4th International Electropalatography (EPG) Symposium, held in Edinburgh in September 2005. *Advances In Speech Language Pathology*, *9*(1), 36-45.

Cohen, S., Labadie, R., Dietrich, M., & Haynes, D. (2004). Quality of life in hearing-impaired adults: the role of cochlear implants and hearing aids. *Otolaryngology-Head & Neck Surgery*, *131*(4), 413-422.

Edwards, B. (2007). The future of hearing aid technology. *Trends In Amplification*, *11*(1), 31-45.

Ertmer, D. J. (2010). Relationships Between Speech Intelligibility and Word Articulation Scores in Children With Hearing Loss. *Journal Of Speech, Language & Hearing Research*, *53*(5), 1075-1086. doi:1092-4388(2010/09-0250)

Geers, A. E. (1986). Vibrotactile stimulation: case study with a profoundly deaf child. *Journal Of Rehabilitation Research And Development*, *23*(1), 111-117.

Guenther, F. H., & Hickok, G. (2015). Role of the auditory system in speech production. *Handbook Of Clinical Neurology*, *129*161-175. doi:10.1016/B978-0-444-62630-1.00009-3

Nanayakkara, S., Wyse, L., & Taylor, E. A. (2012, November). *The Haptic Chair as a Speech Training Aid for the Deaf*. Retrieved March 1, 2018, from https://www.sutd.edu.sg/cmsresource/idc/papers/2012_The_Haptic_Chair_as_a_Speech_Training_Aid_for_the_Deaf.pdf

Öller Darelid, M., Hartelius, L., & Lohmander, A. (2016). Generalised EPG treatment effect in a cochlear implant user maintained after 2 years. *International Journal Of Speech-Language Pathology*, *18*(1), 65-76. doi:10.3109/17549507.2015.1048827

Paatsch, L., Blamey, P., & Sarant, J. (2001). Effects of articulation training on the production of trained and untrained phonemes in conversations and formal tests. *Journal Of Deaf Studies & Deaf Education*, *6*(1), 32-42.

Paul, R. & Norbury, C. (2012). Special considerations for special populations. In *Language disorders from infancy through adolescence: Assessment and intervention, 4th Edition* (pp. 109-112). St. Louis, MO: Mosby.

Plant, G. (1998). Speech training for young adults who are congenitally deaf: a case study. *Volta Review*, *100*(1), 5-17.

Pratt, S. R., Heintzelman, A. T., & Deming, S. E. (1993). The efficacy of using the IBM Speech Viewer Vowel Accuracy Module to treat young children with hearing impairment. *Journal of Speech Language and Hearing Research, 36*(5), 1063. doi:10.1044/jshr.3605.1063

Shuster, L. I., Ruscello, D. M., & Smith, K. D. (1992). Evoking [r] Using Visual Feedback. *American Journal of Speech-Language Pathology, 1*(3), 29. doi:10.1044/1058-0360.0103.29

Sorgini, F., Caliò, R., Carrozza, M. C., & Oddo, C. M. (2018). Haptic-assistive technologies for audition and vision sensory disabilities. *Disability and Rehabilitation. Assistive Technology*, *13*(4), 394-421. doi:10.1080/17483107.2017.1385100

Tourville, J. A., & Guenther, F. H. (2011). The DIVA model: A neural theory of speech acquisition and production. *Language And Cognitive Processes*, *26*(7), 952-981.

Vieu, A., Mondain, M., Blanchard, K., Sillon, M., Reuillard-Artieres, F., Tobey, E., & ... Piron, J.P. (1998). Influence of communication mode on speech intelligibility and syntactic structure of sentences in profoundly hearing impaired French children implanted between 5 and 9 years of age. *International Journal Of Pediatric Otorhinolaryngology*, *44*(1), 15-22.

Types of Biofeedback and Devices

Enhanced Auditory – Altered auditory signal through either a hearing aid or cochlear implant

- Hearing aid:
  - Most common form of enhanced auditory feedback
  - Can be either analog or digital devices
  - Devices use wireless technology to process sounds and provide the auditory information to the user at an increased intensity level
- Cochlear Implant:
  - Most technically sophisticated device for auditory feedback
  - Solely used for people with severe to profound hearing loss
  - Devices are surgically inserted and deliver electrical stimulation through multielectrodes to the inner ear and stimulate the auditory nerve fibers

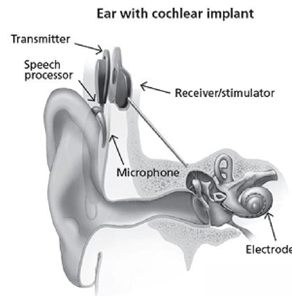

Figure 1- Cochlear implant diagram (National Institute on Deafness and Other Communication Disorders)

Visual – Acoustic equipment processes auditory input and displays it on a monitor

- Electropalatography (EPG) and Glossometry:
  - A dental retainer with electrodes that correspond to specific palatal places of articulation and transmits images of tongue contact to the monitor

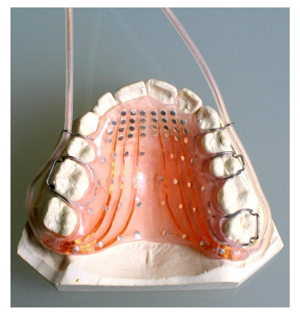

Figure 2- Electropalatography retainer (Articulate Instruments)

- Ultrasound:
  - An ultrasound transducer is placed under the chin of the speaker with the information transmitted to a monitor in real time
- Speech Spectrographic Display (SSD):
  - Shows acoustic energy in a visual representation of frequency, intensity, and timing
  - Information is displayed in a graph of the frequency, timing, and intensity of speech

Tactile – Cues are provided to a body part through touch or vibration in response to placement, coordination, and production of speech

- Tactaid Devices:
  - Wearable device around sternum that delivers vibratory stimulation
  - Basis of majority of research on tactile biofeedback
  - No longer available on the market

Figure 3- Tactaid Device (Health Products For You)

- Haptic Chair:
  - Involves a chair and bracelet that vibrate in response to auditory input and delivers the feedback to various points on the back, armrests, footrests, and accompanying bracelet
- Vibro-tactile Vocoder:
  - Vibrators are placed on the user's arms to deliver vibration in response to auditory input

Efficacy Findings By Age Group

Preschool Children –

- Auditory Feedback:
  - For children who began using hearing aids or CI's within the first 24 months of life, their speech development paralleled that of children with normal hearing more closely than those who received an implant later
  - For children who received a CI between the ages of 2 and 5 years, expressive skills (e.g., rates of utterance growth and grammatical skills) were lower than their typically hearing peers but receptive skills (e.g., vocabulary and literacy skills) were considered within normal limits (Paul & Norbury, 2012)
- Visual Feedback:
  - In a study of 5 children, using the IBM SpeechViewer to target vowels, two improved production of /a/, one improved /i/, and four improved /u/ (Pratt, Heintzelman, & Deming, 1993).
  - Studies have shown inconsistent improvement across participants
- Tactile Feedback:
  - Very limited research with participants in this age range
  - In a study of a 29 month old using the Tactaid I, it was noted that when the device was turned on the child increased number of vocalizations, approximated vowel sounds, and imitated adult speakers (Geers, 1986)

School Aged Children –

- Auditory Feedback:
  - Children using auditory feedback devices demonstrated the ability to generalize targeted phonemes from intervention into their spontaneous speech
  - After receiving speech intervention, 12 children ages 5-10 years old increased intelligibility in spontaneous speech from 42.7% pre-treatment to 47.1% post-treatment (Paatsch, Blamey, & Sarant, 2001)
  - In a study of 12 children who received a cochlear implant within this age range, scores on word intelligibility tests increased from 18% pre-implantation to 54.5% at 36 months post-implantation (Vieu et al., 1998)
- Visual Feedback:
  - Demonstrated positive effects on speech
  - Most prominent effects were noted on vowel production, specifically the four point vowels (/i, æ, u, a/)
  - In studies, the glossometry system and Speech Illumina Mentor (SIM) demonstrated successful remediation of vowels, but the glossometry system resulted in improvement of the /æ/ phoneme while the SIM did not (Jalyani, 1997)
  - In a study using the spectrogram, all 60 participants scored accuracy levels higher than chance in interpreting the visual information, with the accuracy increasing with the age of the participant (Ertmer, 2004)
- Tactile Feedback:
  - Inconclusive findings across participants
  - The Haptic Chair demonstrated the highest levels of improvement for this age range, as it produced the highest levels of word-level intelligibility improvement and reduction of omitted syllables and words across participants (Nanayakkara & Taylor, 2012)

Efficacy Findings By Age Group (continued)

Adults –

- Auditory Feedback:
  - Adults who began using hearing aids and receiving articulation therapy in adulthood did not demonstrate generalization of targeted phonemes in spontaneous speech (Shuster, Ruscello, & Smith, 1992)
  - In a survey of satisfaction with hearing aids, satisfaction ranged from 49-74% across categories such as clearness of sound, comfort with loud sounds, and wind noise. The participants also indicated difficulties using their devices in noisy situations and while chewing or swallowing (Edwards, 2007)
  - In a quality of life questionnaire, hearing aid users indicated lower levels of satisfaction increase following a year of device use compared to cochlear implant users (Cohen et al., 2004)
- Visual Feedback:
  - In a study using electropalatography (EPG), and ultrasound for 6 weeks of intervention, 8 of the 15 vowels targeted showed improvement (Bacsfalvi et al., 2007)
  - In a single case study, production of /g/ in both initial and medial position of words demonstrated significant improvement immediately following treatment as well as at the 3 month, 6 month, and 24 month post maintenance checks (Öller Darelid, Hartelius, & Lohmander, 2016)
- Tactile Feedback:
  - In a single case study using the Tactaid VII, there was a 25% improvement for consonant production and 16.7% improvement in word recognition at the sentence level to unfamiliar listeners (Plant, 1998)
  - In a study comparing types of devices and placement of stimulation, both the multichannel vibrotactile and electrical tactile stimulation systems demonstrated comparable improvements in articulation and intelligibility, as well as pitch and voice control (Sorgini et al., 2018)
  - The level of improvement is directly correlated to the amount of training received

Conclusion

A combination of biofeedback types is suggested for school aged children and adults, as each form demonstrated improvement for differing areas of speech. Visual and tactile are not recommended for the preschool children, as it is assumed these forms of feedback are too complex to be translated at this age. Tactile is not recommended for school aged children as there were inconclusive findings. For adults, each of the feedback systems demonstrated positive effects, indicating the three systems should be paired for optimal and most efficient results.

Age Range	Suggested Form of Biofeedback
Preschool	Auditory
School Aged	Auditory and Visual pairing
Adult	Auditory, Visual, and Tactile pairing

Further research should include analysis of the effects of combined feedback systems, particularly in school aged children and adults.