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

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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 understandable by the listener. As children enter school, their speech intelligibility is often considered an indicator of their abilities, meaning that low intelligibility could exist 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 (Guanter & 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 feedback loop 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 (Touvass & 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, motor control signals associated with each sound they produce, called a target map (Noseworthy & Taylor, 2012).

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 technologically 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

Visual – Acoustic equipment processes auditory input and displays it on a monitor
• Electropalatography (EPG) and Glossometry:
  - A dental retractor with electrodes that correspond to specific palatal places of articulation and transmits images and sounds of tongue contact to the monitor

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
• 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., ratios 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, Heinzeitman, & Denning, 1993).
  - Studies have shown inconsistent improvement across participants

Tactile Feedback:
• Very limited research with participants in this age range
• In a study of 29 month old using the Tactaid II, 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 (Patach, Homey, & Surant, 2001)
• 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 (Elmhurst College- Communication Sciences and Disorders).

Other Communication Disorders

• 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)
• 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 (Elmhurst College- Communication Sciences and Disorders).

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 effective results.

Reference

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