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Effectiveness of the ESTEL Program in Establishing the phonemic System in Children with Hearing Devices

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Abstract

The present study aimed to design and evaluate the effectiveness of a speech rehabilitation program for hearing-impaired children equipped with auditory devices.

The program was developed following a comprehensive review of the research gaps identified in previous studies related to the topic, alongside an examination of the theoretical framework that underpins the current intervention.

The design was guided by the Arabic phonetic developmental chart proposed by Amairah, which served as the primary reference for structuring the training sequence.

The proposed program, entitled ESTEL (Early Speech Training – Ear-Lip), was developed by the researcher to establish both phonemic and phonological systems in children with hearing impairment who use hearing devices.

The program consists of 100 therapeutic sessions divided into two main sections:

• Ear Section: focusing on auditory conditioning and motor pretraining, aiming to enhance auditory discrimination and prepare articulatory movements.

• Lip Section: emphasizing sound shaping and phonetic blending, relying on a set of clinical techniques and therapeutic strategies to achieve the targeted speech outcomes.

The program was applied to a single case study using Zellal's 1984 Phonetic and Phonological Test, within an experimental design framework employing pre- and post-intervention measurements.

The results demonstrated that the proposed ESTEL program effectively facilitated the formation of the phonemic system, improved word articulation, and enhanced short sentence production.

These findings confirm the program's success within the limitations of the current study and suggest that it constitutes a valuable scientific contribution to the field of speech-language pathology for hearing-impaired populations, particularly in the domain of speech rehabilitation.

Keywords:

ESTEL Program – phonemic System – Hearing-Impaired Children – Hearing Devices – Speech Development – Auditory Rehabilitation

Introduction

The category of individuals with hearing impairment represents one of the fortunate groups within the field of special needs that has benefited greatly from technological advancements.

The development of assistive hearing devices has made it possible to stimulate and utilize the remaining auditory residues in order to enhance auditory perception and language development.

These devices vary depending on the type and degree of hearing loss — ranging from hearing aids, which amplify external sounds, to cochlear implants, which directly stimulate the auditory nerve.

The linguistic delay associated with hearing impairment necessitates early intervention immediately following auditory fitting, with the goal of stimulating the emergence of language.

This is then followed by speech-language rehabilitation, which plays a crucial role in improving the individual's quality of life through the enhancement of auditory perception and verbal-linguistic production after amplification.

Initially, specialists and researchers in the field of hearing impairment focused primarily on creating alternative communication methods, such as sign language, lip reading, manual alphabet systems, and total communication, all of which aimed to facilitate social integration.

Subsequently, the focus shifted toward rehabilitative approaches that emphasize linguistic production, particularly through auditory-based methods that rely on developing listening skills to enhance language acquisition.

Numerous studies have confirmed the effectiveness of these auditory approaches in improving verbal output.

In recent years, research attention has turned toward the mechanisms of speech production and the phonetic and articulatory difficulties experienced by individuals with hearing impairment.

Among the most prominent and widely used methods is melodic intonation therapy, which has proven beneficial in stimulating and improving speech articulation in this population. This method opened promising avenues for phonetic and articulatory rehabilitation, paving the way for innovative approaches. Within this framework, the present study aims to design a structured speech rehabilitation program for children with hearing impairment equipped with auditory devices, based on a novel rehabilitative approach in the field.

The program seeks to establish and strengthen both the phonemic and phonological systems, providing a non-traditional therapeutic model for this population.

Objectives

The present study aimed to apply the designed speech rehabilitation program to a non-verbal child with hearing impairment who is equipped with a cochlear implant.

The program sought to develop the child's phonemic and phonological systems within the framework of the local Arabic language.

Through this process, the study aimed to establish the essential foundations for

accurate speech production and phonological awareness in children with hearing impairment.

Significance of the Study

This study represents a scientific and practical contribution to the field of speech and hearing rehabilitation, it responds to the growing need for specialized programs tailored to hearing-impaired children, particularly at early developmental stages.

The research also sheds light on one of the most complex challenges faced by this population—the development of speech intelligibility and the accurate production of sounds after auditory equipment fitting.

Moreover, the study addresses the limited number of research works dedicated to speech rehabilitation among individuals with hearing impairment, especially in Arabic-speaking contexts. I

t highlights the importance of focusing on the phonetic and phonological dimensions of speech rather than solely emphasizing cognitive or educational aspects.

By presenting a structured rehabilitation approach, the study provides speech-language pathologists—especially beginners—with a clear framework for clinical practice and efficient case management, it further encourages practitioners and educators to adopt innovative and evidence-based therapeutic techniques that align with modern trends in auditory and verbal rehabilitation.

Finally, this study calls for a re-evaluation of existing early intervention programs offered to children with hearing aids or cochlear implants, emphasizing the need for individualized and systematic approaches to speech and language development.

.7 Operational Definition of Speech

Speech is defined operationally as the score obtained by a hearing-impaired individual on *Nasira Zellal's Phonemic–Phonological Test* (Zellal, 1984), which evaluates three main dimensions:

The ability to articulate isolated sounds,

The ability to produce sounds within words, and

The ability to produce complete sentences.

A score of 100% is required for the first dimension, and at least 50% for the second and third dimensions to indicate satisfactory phonemic and phonological performance.

2.7 Definition of Hearing Impairment

Hearing impairment refers to a reduction or loss of auditory function due to genetic, congenital, or acquired environmental factors.

The degree of hearing loss may vary from mild to profound, depending on the site and nature of the lesion (Fathi, 2001).

Conductive hearing loss involves damage or dysfunction of the outer or middle ear.

Sensorineural hearing loss results from lesions in the inner ear or auditory nerve.

Central hearing loss is associated with damage in the auditory pathways of the brainstem or the cortical auditory processing centers.

Mixed hearing loss occurs when both conductive and sensorineural components are present.

This impairment can lead to significant consequences in communication, psychological well-being, social adaptation, and professional functioning.

According to *Khaled Bissan* (n.d.), hearing impairment includes two major subgroups:

2.2.7 The Hard-of-Hearing Group

This group experiences partial hearing loss, typically below 70 dB. They retain residual hearing that allows them to benefit from hearing aids or other auditory devices.

2.2.7 The Deaf Group

This group suffers from total hearing loss, estimated at 90 dB or more, indicating the absence of residual hearing. Consequently, they cannot benefit from conventional hearing aids.

3.7 Definition of the Speech Rehabilitation Program

A speech rehabilitation program is a structured and scientifically grounded plan composed of a set of targeted activities, exercises, and therapeutic techniques delivered in well-defined clinical sessions. Each session is organized around specific goals, content, and time parameters, aiming to facilitate speech acquisition and articulation skills among children with hearing impairment (Ibrahim, 2023).

4.7 Definition of Auditory Equipment

According to Heward (2006), auditory equipment refers to assistive hearing devices designed to compensate for hearing deficits by processing and amplifying linguistic information from the acoustic environment.

Two main types are distinguished:

4.1.7 Hearing Aids

Hearing aids are compensatory auditory devices prescribed for individuals with hearing loss who are suitable candidates for amplification. Their use depends on the severity and type of hearing impairment as well as the person's age.

These devices function by stimulating and enhancing residual auditory capacity.

4.2.7 Cochlear Implant

A cochlear implant consists of both surgically implanted internal components and external components worn behind the ear, its function is to provide direct electrical stimulation of the auditory nerve, thereby improving sound perception and enabling access to environmental auditory information (Al-Arabi, 2022).

Previous Studies

The field of auditory and speech training among children with hearing impairments represents one of the key areas of research in *speech-language pathology* and *special education*, it plays a crucial role in developing linguistic communication and enhancing communicative competence following cochlear implantation or the use of hearing aids. Research trends in this field have varied between experimental and analytical approaches, all seeking to identify the effectiveness of intervention programs in improving speech production and auditory perception.

First: Foreign Studies

Foreign research has shown a clear inclination toward the use of rigorous experimental designs to explore the relationship between auditory perception and speech production.

1. Dominic, Massaro, & Giona (2004)

This study is among the earliest applied works focusing on the effectiveness of direct speech training in improving both auditory perception and linguistic production among children with hearing impairments.

The sample included seven hearing-aided children aged between 8 and 13 years. The

researchers used an experimental design with pre-test and post-test measurements. A diagnostic tool known as the *Cooter Articulation Assessment* was employed to analyze articulatory learning traits and sound leakage during speech production. The results revealed a significant improvement in sound articulation and speech fluency after applying the program, with positive responsiveness to the proposed method, which emphasizes syllabic training before progressing to full words.
(Dominic et al., 2004)

2. Angelique & Madha Adhani (2009) This longitudinal study investigated the effectiveness of the *Home Auditory Program (HAP)* for children with cochlear implants over a three-year period. The sample consisted of 18 children aged 4–11 years. Using an experimental approach and a customized auditory perception scale, the study demonstrated significant improvements in auditory performance and perception, regardless of implant type or spoken language. The findings suggest that structured and intensive home-based auditory training enhances comprehension, auditory discrimination, and post-implant rehabilitation outcomes. *(Angelique & Adhani, 2009)*

Second: Arabic Studies

Recent Arabic studies have increasingly adopted experimental and applied approaches in auditory speech pathology, testing the effectiveness of auditory-verbal and speech training programs at early developmental stages.

1. Ibrahim Hassan Abu Aleem & Mahmoud Zaid Al-Malkawi (2010) This study examined the effectiveness of a computer-based verbal training program for hearing-impaired preschoolers. The sample included 30 hearing-aided children, and the researchers used a quasi-experimental design featuring digital voice-based exercises focusing on short and long vowel articulation within different word positions.
Results indicated the program's effectiveness in improving speech accuracy and phoneme production, highlighting the role of technological media in fostering interactive learning and strengthening auditory memory. *(Abu Aleem & Al-Malkawi, 2010)*

2. Abdelrahman Naqqara (2010) This study explored the impact of auditory-verbal rehabilitation programs on improving speech skills among preschool children with cochlear implants. The sample consisted of 30 children aged 3–5 years.
The program used meaningless phonological syllables as auditory training stimuli.
Findings revealed notable improvement in phoneme articulation and syllable comprehension, confirming that targeted phonological training significantly contributes to reconstructing speech patterns after cochlear implantation. *(Naqqara, 2010)*

3. Mahmoud Zaid Mohammad Al-Malkawi (2011)
The study aimed to assess the effectiveness of a training program designed to improve the articulation of selected Arabic phonemes among hearing-impaired children.
Using an image-naming test within an experimental design, the researcher found significant development in articulatory and auditory discrimination abilities—

particularly when combining auditory and visual cues—underscoring the importance of multisensory integration in speech-language intervention for this population. *(Al-Malkawi, 2011)*

4. Mervat Bayoumi (2011) This research investigated the use of *representational speech* in reducing articulation disorders among deaf children.

The program was implemented with 16 children across three stages: preparatory activities, training on names and letters using alphabetic and manual signs, and finally, sentence-level production. Results showed higher language acquisition rates in the experimental group compared to the control group, demonstrating the therapeutic value of symbolic and dramatic activities in stimulating speech and facilitating linguistic expression. *(Bayoumi, 2011)*

Main Study Framework

1. Research Design

The applied component represents the core of any scientific study, as it allows for the verification of theoretical assumptions and the validation of empirical findings. In this context, the present research seeks to detail the methodological steps followed in the fieldwork phase to achieve its objectives.

1.1 Experimental Method

The experimental method is a research approach that emphasizes controlled experimentation and scientific testing. It provides reliable and objective results, as it relies on systematic procedures and standardized tools that allow for the empirical verification of research questions and hypotheses formulated during the study.

1.2 Rationale for Choosing the Experimental Method

- The experimental design is the most appropriate and relevant approach for the objectives and nature of the present study.
- It enables the researcher to verify the study's hypotheses and respond effectively to the research questions.

Methodology

1. Research Procedures

The practical aspect of any study represents the essential core that enables researchers to verify the information under investigation.

Accordingly, this section outlines all the steps followed in the field phase to complete the current study.

1.1. Research Design

1.1.1. Experimental Method

The experimental method is a research approach based on controlled testing and scientific verification. It allows for highly valid and objective results through the use of precise tools that help confirm the research hypotheses by subjecting them to experimental testing.

1.1.2. Rationale for Choosing the Experimental Method

- The experimental approach was the most appropriate for the nature of this study.
- It allowed the researcher to empirically verify the research questions.
- It enabled the attainment of measurable and reliable results consistent with the study objectives.

2. Study Boundaries

2.1. Spatial Boundaries

The study was conducted at *El-Amel Orthophonic Clinic*, located in Merouana district, Batna province (Algeria).

Justification for Site Selection:

- Difficulty in finding a facility that met all the conditions required for the duration of the program.
- The clinic represents the researcher's workplace, facilitating close follow-up.
- The site provided optimal conditions for the application and monitoring of the rehabilitation program.
- The clinic's facilities allowed for continuous and structured intervention.

2.2. Temporal Boundaries

The study extended over the academic years 2021–2022, including the design and validation of the rehabilitation program.
The experimental phase was implemented between December 2022 and November 2023, providing sufficient time for observation and evaluation.

3. Study Sample

A purposive sampling technique was adopted, selecting one child who met the inclusion criteria of the designed rehabilitation program.

The selection relied on the following conditions:

- Age range between 4 and 7 years.
- Equipped with an auditory device (cochlear implant).
- Had not previously received intensive or long-term orthophonic therapy.
- Demonstrated an adequate level of intellectual functioning to benefit from therapy.
- Presented no organic or functional deficits in the speech apparatus.
- Did not exhibit psychological or behavioral disorders that could interfere with intervention outcomes.

4. Research Instruments

4.1. Case Study Approach

The case study method was employed as it aligns with the objectives of the present research.

This method allowed for a comprehensive understanding of the subject's medical and developmental history, as well as detailed documentation of therapeutic progress and contextual factors.

4.2. Nasira Zellal's Phonetic and Phonological Test (1984)

The *Bilan Phonétique et Phonologique de Nasira Zellal* (1984) was used to assess phoneme acquisition and mastery within words and sentences.

This test was selected due to the scarcity of phonemic assessment tools designed specifically for children with hearing impairments, and for its ease of administration and reliability in evaluating speech performance. The test comprises five main subtests:

1. Isolated sounds.
2. Sounds in the initial position of the word.
3. Sounds in the medial position.
4. Sounds in the final position.
5. Sounds within full sentences.

The ESTEL Program (Early Speech Training – Ear-Lip)

The ESTEL Program — *Early Speech Training: Ear-Lip* — is a comprehensive speech rehabilitation program designed for children with hearing impairments equipped with auditory devices.

It targets the post-fitting phase, which represents a critical period for early intervention, aiming to stimulate residual hearing and maximize its potential to support language development.
The program was conceptualized and developed by the researcher as part of the current study.

This program is specifically intended for orthophonists and speech-language specialists working with hearing-impaired children after cochlear implantation or hearing aid fitting.
It comprises 100 therapeutic sessions, organized into two main parts, each subdivided into distinct submodules:

1. The Ear Component

This section focuses on developing auditory and motor readiness and includes two submodules:

- Auditory Preparation Module: Aims to enhance auditory perception, discrimination, and memory.
- Motor Preparation Module: Seeks to improve both gross and fine motor skills required for articulatory control.

2. The Lip Component

This section emphasizes the development of articulatory precision and phonological organization and includes two submodules:

- Phonemic Formation Module: Targets the acquisition and establishment of the phonemic system.
- Phonological Integration Module: Aims to develop the phonological system, focusing on sound sequencing and speech intelligibility.

Session Structure

Each therapeutic session follows a unified framework including:

- Session Number and Title
- Type of Session
- Tools and Materials Used
- Techniques Applied
- Duration
- Implementation Procedure

All sessions are structured according to these components to ensure systematic progression and therapeutic consistency.

Techniques and Therapeutic Approaches

The program integrates behavioral therapy principles, emphasizing stimulus–response conditioning to elicit the desired speech behaviors. Techniques and strategies vary according to the objectives and focus of each module. They include:

- Active Listening
- Observation
- Shaping
- Imitation
- Modeling
- Prompting (Cueing)
- Feedback (Reinforcement)
- Auditory Bombardment
- Positive Reinforcement

Each session's technique was selected according to its specific objective, ensuring that the intervention remains targeted, measurable, and adaptive to the child's progress.

Implementation Procedures of the ESTEL Program

1. Pre-Test (Phonetic and Phonological Assessment – Nasira Zellal Test)

After confirming the child's cognitive level, the Nasira Zellal Phonetic and Phonological Test was administered. At the beginning of the session, the researcher prepared the activity, explaining its purpose and implementation process.

The child indicated comprehension by nodding. During the articulation of target sounds, the child often requested multiple repetitions, particularly for pharyngeal sounds and acoustically similar phonemes.
It was observed that the child was unable to produce most of the sounds,

often signaling inability through gestures. Repeated attempts led to signs of tension and frustration. In conclusion, the child failed to complete the phonetic test successfully, being able to pronounce only the labial sounds /b/, /m/, and
/w/. All other sounds could not be produced.

2. Program Implementation

The ESTEL program was implemented from late 2022 to late 2023, during which all 100 therapeutic sessions were successfully conducted without interruption.

The child maintained consistent attendance and showed active participation during all sessions.

The success of the program implementation was supported by several factors, such as the child's cooperation, family support, and the therapist's structured guidance.

3. Post-Test (Phonetic and Phonological Re-Assessment)

In the post-intervention phase, the Nasira Zellal phonetic and phonological test was re-administered to evaluate the child's progress across different levels of sound production. The results revealed a remarkable improvement compared to the pre-test scores.

The child's performance in isolated sound production increased from 7.14% in the pre-test to 100% in the post-test, indicating full acquisition of isolated phonemes.

In word-initial position, scores improved from 3.57% to 89.28%, reflecting substantial development in articulatory control at the onset of words.

Similarly, a significant improvement was observed in the word-medial position, where accuracy rose from 3.18% before intervention to 82.14% afterwards, suggesting enhanced stability and precision of sound production within syllabic structures. In the word-final position, performance progressed from 3.57% to 92.85%, demonstrating better airflow management and articulatory closure at the end of words.

For sentence-level production, which represents the most complex level due to increased motor and linguistic demands, the score improved from 0% in the pre-test to 71.42% in the post-test.

This indicates a successful transfer of acquired skills to more natural and contextually embedded speech.

Overall, these findings show consistent and substantial improvement across all domains of phonetic and phonological performance, confirming the effectiveness of the therapeutic program

4. Analysis of Results

The results reveal a marked improvement between pre- and post-test scores across all variables.

Pre-Test Findings

Pre-test results indicated very low performance in isolated sound production and in producing sounds within words and sentences.

- For isolated sounds, the child scored 7.14%, reflecting a near absence of a functional phonemic system, with only minimal production of labial sounds.
- For sounds in words, the scores were 3.57% (initial), 3.18% (medial), and 3.57% (final) — extremely low and nearly null values.
- For sentences, the score was 0%, confirming the inability to produce structured speech.

These results highlight that despite being equipped with a hearing device, the child lacked the fundamental phonemic system, making the articulation of words impossible.

Post-Test Findings

Post-test results demonstrate the efficacy of the ESTEL program.

- Isolated sounds reached 100%, indicating full acquisition of the phonemic repertoire.
- Word-level phonological production improved significantly: 89.28% (initial), 82.14% (medial), and 92.85% (final).
- Sentence-level articulation reached 71.42%, reflecting improved phonological sequencing and speech intelligibility.

5. Discussion of the Second Research Question

Research Question: *the effectiveness of the ESTEL program in developing the phonemic and phonological systems of a non-verbal hearing-impaired child with a cochlear implant?*

The obtained results confirm the success of the ESTEL program. The program was designed to address all interrelated components of speech production, starting from auditory perception to articulatory motor execution. Through structured training, the child successfully acquired the phonemic system, progressing from isolated sounds to syllables, words, and eventually complete sentences.

A key aspect of the program was its focus on auditory stimulation and sensory-motor integration:

- The auditory component enhanced auditory perception, discrimination, and memory, promoting automatic auditory responses and improving central auditory processing.
- The motor component targeted motor coordination, particularly orofacial movements, facial massage, and fine motor gestures, all of which support articulatory precision.
- Breathing training was incorporated to optimize respiratory control, essential for accurate phoneme articulation.

Thus, the ESTEL program effectively addressed the multi-dimensional challenges faced by children with hearing impairments during speech acquisition, improving both auditory and articulatory mechanisms.

Conclusion

In the present study, we sought to design a speech rehabilitation

program tailored for children with hearing impairments, grounded on theoretical foundations and methodological principles that take into account all the difficulties affecting the various mechanisms involved in the speech production process. The program aimed to correct and strengthen the weak links within these mechanisms and was divided into two main components:

- The EAR component, focusing on auditory reception, and comprising two axes: auditory perception and sensory-motor readiness.
- The LIP component, focusing on speech production, and including phoneme articulation and phonological sequencing.

The program was implemented using the Nasira Zellal Phonetic and Phonological Test, within a single-case experimental design that incorporated both pre- and post-assessments to address the study's research questions. The results showed that the designed program effectively enabled the child to form and master all phonemes, and to articulate sounds accurately within words. This, in turn, encouraged lexical enrichment, allowing the child to develop and use new words in meaningful contexts. Furthermore, the child was able to use speech fluently, with appropriate temporal pauses, and good control of speech flow.

Notably, the child demonstrated spontaneous self-correction when encountering articulation difficulties, reflecting significant improvement in speech awareness and monitoring.

The ESTEL program enabled the child to:

- Acquire and articulate all phonemes correctly.
- Produce sounds within words and sentences with fluency.
- Expand lexical repertoire and use words spontaneously.

Control speech flow and pausing, showing self-correction strategies.

In conclusion, this study represents a novel contribution to the field of speech-language rehabilitation for hearing-impaired individuals with auditory prostheses. Through the design of a structured therapeutic program focused on speech production, the study succeeded in achieving its primary goal — the establishment of both phonemic and phonological systems in the target child, thereby confirming the efficacy of the proposed ESTEL program.

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