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METHODOLOGY FOR THE NEUROCOGNITIVE STUDY OF ACOUSTIC-PERCEPTUAL ABILITIES AND LINGUISTIC FUNCTION IN PRETERM INFANTS

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ABSTRACT

Due to the convergence of Applied Linguistics (in particular, Clinical Linguistics), Acoustic Engineering and the Neonatology Unit of the University Hospital Puerta del Mar in Cadiz, the aim of this study is to conduct a longitudinal neurocognitive study of acoustic-perceptual skills and linguistic function in preterm infants. This will allow to establish the interrelation between both aspects during the 0 to 4 years' stage, to identify possible deficiencies and their manifestation in different stages and, consequently, to achieve better diagnostic and treatment protocols for this population. For this purpose, clinical data, especially neuroimaging data, are contrasted with those derived from the evaluation of the influence of noise exposure in incubators on sensorineural hearing loss and auditory maturation by means of electrophysiological and acoustic techniques.
As for the results, it is expected that the analysis of the data obtained will shed light on the possible auditory and linguistic deficiencies observed, in addition to the design of appropriate specific audiological and speech therapy tools.

Keywords: *neonatology, linguistics, acoustic, audiology, neurocognitive study*

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1. INTRODUCTION

This study is ascribed to the project "Longitudinal and cross-sectional neurocognitive study of acoustic-perceptual abilities and linguistic function in preterm infants (PretermLA)", funded by the Research Plan of the University of Cadiz (code PR2024-010), within its call for Bridge Projects (2024/2025).
Preterm birth is associated with a spectrum of neurological, cognitive, and linguistic complications [1]. Multiple studies have documented language disorders and deficits in auditory speech processing linked to prematurity and low birth weight [2]. Research indicates that language performance in preterm children shows differences that persist over time, suggesting long-term stability of linguistic vulnerabilities [3,4].
The relationship between prematurity and language development has been extensively investigated, with findings consistently showing that premature birth poses risks for various aspects of linguistic development. These children demonstrate unique trajectories in language acquisition that differ from their full-term counterparts [4]. Neuroimaging studies have revealed altered brain connectivity in premature infants, with extremely preterm children exhibiting increased interhemispheric connectivity for language [5]. Additionally, white matter microstructure has been associated with language abilities in children born very preterm [6].
A critical element often overlooked in this context is the acoustic environment of premature infants. Exposure to incubator noise in Neonatal Intensive Care Units (NICUs) constitutes a risk factor that can lead to stress-related

functional impairments, potentially causing hearing loss [7] and affecting physiological parameters including heart rate, respiratory rate, and oxygen saturation [8]. These early acoustic experiences occur during a crucial period when language acquisition and acoustic-perceptual skills are beginning to develop, with neural encoding of voice pitch and formant structure already present at birth [9].

Despite the substantial evidence linking prematurity to language disorders, there is a significant research gap concerning the longitudinal study of language development in parallel with the perception of speech sounds during early childhood. Previous research has demonstrated through studies of Mismatch Negativity (MMN) that phonological processing at early ages can be an important prognostic factor for predicting future language development in at-risk populations [10]. However, a comprehensive approach combining acoustic assessment, language development, and neurophysiological markers throughout early childhood is still needed.

The present longitudinal study aims to address this research gap by examining the influence of the acoustic environment, particularly incubator noise, on neurocognitive development for language function in premature infants from birth to 4 years of age. By adopting a multidisciplinary approach that combines expertise in acoustic engineering, clinical linguistics, and neuropediatric, this research seeks to provide a deeper understanding of the relationship between early acoustic experiences and linguistic development in premature children.

2. METHODOLOGY

This research employs a longitudinal design with a multidisciplinary approach combining acoustic engineering, clinical linguistics, and neuropediatrics to comprehensively assess the development of language functions in premature infants.

The sample of this research is divided into two groups: an experimental group (EG) and a control group (CG). The experimental group will be composed of between 20 and 50 preterm neonates born at the Hospital Universitario Puerta del Mar during the first year of the project. The inclusion criteria for this group are birth weight less than 1,500 grams or gestational age less than 32 weeks. As for the control group, it will be made up of a similar number of full-term newborns, who will be selected without any pathological condition affecting their linguistic or neurocognitive development.

Sample size calculation was based on previous literature, aiming to detect a minimum effect size of 11.6 points on linguistic tests with 80% power and an alpha risk of 0.05, requiring at least 28 participants per group. Accounting for potential follow-up losses (10%), the target sample size is 31 participants per group.

2.1 Data collection procedures

The methodology of this research is organized in three interconnected blocks. The first, Biomedical Acoustics, focuses on the assessment of auditory thresholds and physiological responses in premature infants, taking into account factors such as stress and exposure to sounds in the incubator. This block utilizes evoked potentials, otoacoustic emissions, and electroencephalograms, employing acoustic stimuli at varying sound pressure levels to achieve this objective. The second block, Clinical Linguistics, focuses on the assessment of language development using standardized tests and the analysis of early vocal production. Speech intelligibility and neurocognitive responses to linguistic stimuli are measured using specialized tools. Early vocal production is analyzed through the recording and processing of manifestations such as crying, gurgles, babbling, and syllabic production, using specialized tools such as PRAAT. The Acoustic-Linguistic Integration block serves to synthesize the data obtained in the two preceding blocks. In this block, statistical analyses are performed to identify significant patterns in the auditory and linguistic development of preterm infants.

3. EXPECTED RESULTS

It is imperative to acknowledge that this research is still in its developmental stage; therefore, the findings obtained thus far should not be considered conclusive.

This research is expected to yield significant findings in several key areas. First, it will provide a comprehensive understanding of acoustic-perceptual and linguistic development in preterm infants, offering detailed data on the acquisition and progression of phonetic-phonological, lexical-semantic, morphosyntactic, and pragmatic skills in this population compared to full-term infants. This will enable the identification of specific developmental trajectories for preterm infants.

Second, the impact of incubator noise on neurodevelopment will be assessed by quantifying the relationship between acoustic conditions and physiological variables such as brain waves, heart rate, oxygen saturation, and sleep patterns. This analysis will be essential in defining safety

thresholds and establishing evidence-based recommendations for NICUs acoustic environments.

Consequently, the present study will concentrate on identifying specific impairments in acoustic and linguistic processing to characterize potential alterations in perceptual mechanisms among preterm infants. This will entail a meticulous examination of auditory thresholds across diverse frequency ranges and their correlation with linguistic development. Furthermore, the neuroanatomical underpinnings of language development will be investigated by integrating acoustic-perceptual and linguistic data with neuroimaging findings, particularly tractography. This comprehensive approach is expected to elucidate the functional neuroanatomical underpinnings of language acquisition in this particular population [6].

This research also aims to develop innovative assessment and intervention protocols. Utilizing the longitudinal data collected, integrated acoustic-perceptual and linguistic assessment protocols will be designed to facilitate the early identification of developmental disturbances in preterm infants, accompanied by personalized therapeutic intervention guidelines.

This research endeavors to enhance the existing body of knowledge concerning auditory maturation in preterm infants. This enhanced understanding is imperative for determining the optimal timing of interventions, such as cochlear implantation in cases of severe hearing loss [11]. Furthermore, the study will establish associations between early environmental factors and various aspects of neurobehavioral and developmental profiles in this population, thereby expanding upon previous research on very low birth weight preterm infants [12].

4. CONCLUSIONS

This longitudinal neurocognitive study addresses a critical research gap in understanding how the acoustic environment, particularly incubator noise, influences neurocognitive development for language function in premature infants. By adopting a multidisciplinary approach that combines acoustic engineering, clinical linguistics, and neuropediatrics, this study aims to provide comprehensive insights into the complex interplay between early acoustic experiences and linguistic development.

The research has significant theoretical and practical implications. From a theoretical perspective, it will contribute to linguistic theory by optimising hypotheses on the nature of the language faculty and developing connections between linguistics and other sciences. This may promote a paradigm shift within Biolinguistics and Clinical Linguistics by developing models of language and its disorders based on the interaction between biological and environmental factors.

From a practical standpoint, the findings will have immediate applications in clinical settings. The data on hearing thresholds and auditory pathway maturation would help improve protocols for early identification and treatment of hearing problems in premature children. The integrated assessment protocols and intervention guidelines developed through this research could be incorporated into routine clinical practice, potentially improving outcomes for premature infants.

The social impact of this research is substantial, as it addresses the needs of a vulnerable population. By improving our understanding of the environmental factors that affect neurodevelopment in premature infants, the investigation contributes to reducing social inequalities and enhancing early diagnosis methods. The results will be valuable not only to healthcare professionals but also to families, educators, and other stakeholders involved in supporting the development of premature children.

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