Objective Prediction of Pure Tone Thresholds in Normal and Hearing-Impaired Ears with Distortion Product Otoacoustic Emissions and Artificial Neural Networks

by

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Abstract

Title	:	Objective Prediction of Pure Tone Thresholds in Normal and Hearing-Impaired Ears with Distortion Product Otoacoustic Emissions and Artificial Neural Networks
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In the evaluation of special populations, such as neonates, infants and malingerers, audiologists have to rely heavily on objective measurements to assess hearing ability. Current objective audiological procedures such as tympanometry, the acoustic reflex, auditory brainstem response and transient evoked otoacoustic emissions, however, have certain limitations, contributing to the need of an objective, non-invasive, rapid, economic test of hearing that evaluate hearing ability in a wide range of frequencies. The purpose of this study was to investigate distortion product otoacoustic emissions (DPOAEs) as an objective test of hearing. The main aim was to improve prediction of pure tone thresholds at 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz with DPOAEs and artificial neural networks (ANNs) in normal and hearing-impaired ears. Other studies

that attempted to predict hearing ability with DPOAEs and conventional statistical methods were only able to distinguish between normal and impaired hearing.

Back propagation neural networks were trained with the pattern of all present and absent DPOAE responses of 11 DPOAE frequencies of eight DP Grams and pure tone thresholds at 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz. The neural network used the learned correlation between these two data sets to predict hearing ability at 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz. Hearing ability was not predicted as a decibel value, but into one of several categories spanning 10dB.

Results for prediction accuracy of normal hearing improved from 92% to 94% at 500 Hz, 87% to 88% at 1000 Hz, 84% to 88% at 2000 Hz and 91% to 93% at 4000 Hz from the De Waal (1998) study to the present study. The improvement of prediction of normal hearing can be attributed to extensive experimentation with neural network topology and manipulation of input data to present information to the network optimally. The prediction of hearing-impaired categories was less satisfactory, due to insufficient data for the ANNs to train on. A prediction versus ear count correlation strongly suggested that the inaccurate predictions of hearing-impaired categories is not a result of an inability of DPOAEs to predict pure tone thresholds in hearing impaired ears, but a result of insufficient data for the neural network to train on.

This research concluded that DPOAEs and ANNs can be used to accurately predict hearing ability within 10dB in normal and hearing-impaired ears from 500 Hz to 4000 Hz for hearing losses of up to 65dB HL.

Key words: otoacoustic emissions, distortion product otoacoustic emissions, artificial neural networks, prediction of hearing threshold, age and gender, objective hearing assessment.

Opsomming

Titel	:	Objektiewe voorspelling van Suiwertoondrempels in Normale en Gehoorgestremde ore met behulp van Distorsie Produk Otoakoestiese Emissies en Kunsmatige Neurale Netwerke
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In die evaluasie van spesiale populasies, soos neonate, kleuters en persone wat gehoorverliese voorgee, moet oudioloë dikwels steun op objektiewe metings om gehoorvermoë te evalueer. Huidige objektiewe oudiologiese prosedures, soos timpanometrie, die akoestiese refleks, ouditiewe breinstam respons en transient-ontlokte otoakoestiese emissies, het egter soveel tekortkominge, dat daar steeds 'n behoefte bestaan vir 'n objektiewe, vinnige en ekonomiese toetsprosedure, wat suiwertone in 'n wye frekwensiegebied evalueer. Die doel van hierdie studie was, om distorsie produk otoakoestiese emissies (DPOAEs) te ondersoek as a moontlike nuwe objektiewe gehoortoets. Die hoofdoel van die studie was om suiwertoondrempel

voorspelling te verbeter by 500 Hz, 1000 Hz, 2000 Hz en 4000 Hz met DPOAEs en kunsmatige neurale netwerke in normale en gehoorgestremde ore. Ander studies wat gepoog het om gehoorvermoë te voorspel met DPOAEs en statistiese metodes, was slegs in staat om tussen normale en gehoorgstremde ore te onderskei.

Neurale netwerke is opgelei met die patroon van alle aanwesige en afwesige DPOAE response van 11 DPOAE frekwensies en agt DP Gramme, sowel as suiwertoondrempels by 500 Hz, 1000 Hz, 2000 Hz en 4000 Hz. Die neurale netwerk het die geleerde korrelasie tussen die twee data stelle toegepas om gehoorvermoë te voorspel by 500 Hz, 1000 Hz, 2000 Hz en 4000 Hz. Gehoorvermoë is nie as 'n desibel waarde voorspel nie, maar in 'n kategorie met 'n grootte van 10dB.

Resultate het bevind dat voorspellingsakkuraatheid van normale gehoor verbeter het van 92% tot 94% by 500 Hz, 87% tot 88% by 1000 Hz, 84% tot 88% by 2000 Hz en 91% tot 93% by 4000 Hz van die vorige studie (De Waal, 1998) tot die huidige studie. Die verbetering in voorspellingsakkuraatheid kan toegeskryf word aan uitgebreide eksperimentering met neurale netwerk topologie en manipulering van inset data om optimale voorstelling van inligting in neurale netwerk opleiding te bewerkstellig. Die voorspellings van kategorie waardes by gehoorgestremdheid was minder bevredigend weens onvoldoende data vir die opleiding van die neurale netwerk. Die voorspellingsakkuraatheid versus die hoeveelheid ore in elke kategorie is met mekaar gekorreleer. Hierdie bevinding dui daarop dat die onvermoë om kategorië met gehoorverliese te voorspel, nie 'n tekortkoming van DPOAEs as suiwertoonvoorspeller is nie, maar 'n gevolg is van die onvoldoende data wat die neurale netwerk gehad het in die opleidingsfase.

Die gevolgtrekking van hierdie studie dui daarop dat DPOAEs en neurale netwerke gebruik kan word om gehoorvermoë binne 10dB akkuraatheid te voorspel in normale en gehoorgestremde ore, van 500 Hz tot 4000 Hz vir gehoorverliese tot en met 65dB.

Sleutelwoorde: otoakoestiese emissies, distorsie produk otoakoestiese emissies, neurale netwerke, voorspelling van gehoordrempels, ouderdom en geslag, objektiewe meting van gehoorvermoë.

Table of Contents:

List of tables:

List of Figures:

List of Appendices:

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Abbreviations Used in this Study:

2f1-f2	:	The cubic distortion frequency in DPOAE testing
ABLB	:	Alternate Binaural Loudness Balance
ABR	:	Auditory Brainstem Response
AEPs	:	Auditory Evoked Potentials
ANNs	:	Artificial Neural Networks
ANS	:	Artificial Neural System
ART	:	Acoustic Reflex Threshold
BBN	:	Broadband Noise
dB	:	decibel
DP	:	Distortion Product
DP Gram	:	Distortion Product Audiogram
DPOAEs	:	Distortion Product Otoacoustic Emissions
EcochG	:	Electrocochleography
EEG	:	Electroencephalogram
EOAEs	:	Evoked Otoacoustic Emissions
f1 or f2	:	The primary frequencies in DPOAE testing
GM	:	Geometric Mean
HL	:	Hearing Level
Hz	:	Hertz
I/O Function	:	Input/ Output Function
L1 or L2	:	Loudness levels of the primary frequencies in DPOAE testing
LLR	:	Long Latency Response
MLR	:	Middle Latency Response
NPR	:	Negative Predictive Value

OAEs	:	Otoacoustic Emissions
OHC	:	Outer Hair Cells
PPV	:	Positive Predictive Value
PTA	:	Pure Tone Average
PTTs	:	Pure Tone Thresholds
SFOAEs	:	Stimulus Frequency Emissions
SLRs	:	Short Latency Responses
SOAEs	:	Spontaneous Otoacoustic Emissions
SPAR	:	Sensitivity Prediction with the Acoustic Reflex
SPL	:	Sound Pressure Level
TBOAEs	:	Tone Burst Otoacoustic Emissions
TEOAEs	:	Transient Evoked Otoacoustic Emissions