The Use of Artificial Neural Networks to Predict Pure Tone Thresholds in Normal and Hearing- Impaired Ears with Distortion Product Otoacoustic Emissions

by

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Abstract

Title : The Use of Artificial Neural Networks to Predict Pure Tone Thresholds in Normal and Hearing- Impaired Ears with Distortion Product Otoacoustic Emissions

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In the evaluation of special populations, such as neonates, infants and malingerers, audiologist often 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 attempt to predict hearing ability 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 10-15dB.

Results indicated that prediction accuracy of normal hearing was 92% at 500 Hz, 87% at 1000 Hz, 84% at 2000 Hz and 91% at 4000 Hz. The prediction of hearing-impaired categories was less satisfactory, due to insufficient data for the ANNs to train on. The variables age and gender were included in some of the neural network runs to determine their effect on the distortion product. Gender had only a minor positive effect on prediction accuracy, but age affected prediction accuracy considerably in a positive way. The effect of the amount of data that the neural network had to train on was also investigated. 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 : Die 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

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

Neurale netwerke is opgelei met die partoon 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 10-15dB.

Resultate het gedui op voorspellingsakkuraatheid van normale gehoor van 92% by 500 Hz, 87% by 1000 Hz, 84% by 2000 Hz en 91% by 4000 Hz. Die voorspellings van kategorie waardes by gehoorgestremdheid was minder bevredigend weens onvoldoende data vir die opleiding van die neurale netwerk. Die veranderlikes ouderdom en geslag, is ook ingesluit in sommige van die neurale netwerke om die effek daarvan te bepaal op die distorsie produk. Geslag het slegs 'n minimale positiewe effek op voorspellingsakkuraatheid gehad, maar ouerdom het die voorspellingsakkuraatheid van die neurale netwerk aansienlik verbeter. Die uitwerking van die hoeveelheid data in elke kategorie wat beskikbaar was vir die neurale netwerk in die opleidingsfase op voorspellingsakkuraatheid, is ook ondersoek.

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 is nie, maar as gevolg 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.

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Abbreviations Used in this Study

ABLB	:	Alternate Binaural Loudness Balance
ABR	:	Auditory Brainstem Response
AEPs	:	Auditory Evoked Potentials
ANNs	:	Artificial Neural Networks
ANS	:	Artificial Neural System
dB	:	decibel
DP	:	Distortion Product
DP Gram	:	Distortion Product Audiogram
DPOAEs	:	Distortion Product Otoacoustic Emissions
EcochG	:	Electrocochleography
EEG	:	Electroencephalogram
EOAEs	:	Evoked Otoacoustic Emissions
GM	:	Geometric Mean
HL	:	Hearing Level
Hz	:	Hertz
I/O Function	:	Input/ Output Function
LLR	:	Long Latency Response
MLR	:	Middle Latency Response
OAEs	:	Otoacoustic Emissions
OHC	:	Outer Hair Cells
PTA	:	Pure Tone Average
PTT	:	Pure Tone Threshold
SFEs	:	Stimulus Frequency Emissions

SISI	:	Short Increment Sensitivity Index
SLRs	:	Short Latency Responses
SOAEs	:	Spontaneous Otoacoustic Emissions
SPAR	:	Sensitivity Prediction with the Acoustic Reflex
SPL	:	Sound Pressure Level
TEOAEs	:	Transient Evoked Otoacoustic Emissions