



**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 gehoorgestremde 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 kategorieë 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.



1	INTRODUCTION, ORIENTATION, AND RATIONALE	1
1.1	INTRODUCTION	1
1.2	OVERVIEW OF OBJECTIVE DIAGNOSTIC PROCEDURES IN AUDIOLOGY	1
1.3	OTOACOUSTIC EMISSIONS	7
1.3.1	SPONTANEOUS OTOACOUSTIC EMISSIONS (SOAES).....	8
1.3.2	STIMULUS FREQUENCY OTOACOUSTIC EMISSIONS (SFES).....	9
1.3.3	TRANSIENT EVOKED OTOACOUSTIC EMISSIONS (TEOAES).....	10
1.3.4	DISTORTION PRODUCT OTOACOUSTIC EMISSIONS (DPOAES)	14
1.4	RATIONALE FOR THIS STUDY.....	15
2	DISTORTION PRODUCT OTOACOUSTIC EMISSIONS.....	18
2.1	INTRODUCTION TO DISTORTION PRODUCT OTOACOUSTIC EMISSIONS	18
2.2	DEFINITION OF DPOAE	19
2.3	MEASUREMENT PROCEDURES AND INSTRUMENTATION FOR DPOAES.	20
2.4	STIMULUS PARAMETERS OF DPOAES.....	23
2.5	DP GRAM VERSUS I/O FUNCTION.....	25
2.5.1	THE DP GRAM	25
2.5.2	THE I/O FUNCTION.....	26
2.6	PREVALENCE OF DPOAES IN NORMAL HEARING AND HEARING IMPAIRED POPULATIONS	29
2.7	THE EFFECT OF AGE AND GENDER ON DPOAES	33
2.8	FREQUENCY SPECIFICITY OF DPOAE MEASUREMENTS.....	36
2.9	RELATION OF THE DISTORTION PRODUCT TO AUDITORY SENSITIVITY	41



2.10	LIMITATIONS OF PREVIOUS STUDIES INVESTIGATING POSSIBLE CORRELATION BETWEEN DPOAES AND PURE TONE AUDIOMETRY	48
2.11	SUMMARY	50
3	<u>ARTIFICIAL NEURAL NETWORKS</u>	51
3.1	INTRODUCTION	51
3.2	OVERVIEW OF HISTORY AND DEVELOPMENT OF ARTIFICIAL NEURAL NETWORKS	52
3.3	DEFINITION OF ARTIFICIAL NEURAL NETWORKS	54
3.4	“ANATOMY” AND “PHYSIOLOGY” OF ARTIFICIAL NEURAL NETWORKS: A DISCUSSION OF CONCEPTS AND TERMS	54
3.4.1	BIOLOGICAL NEURAL NETWORKS	55
3.4.2	ARTIFICIAL NEURAL NETWORKS (ANNs):	56
3.5	DIFFERENT TYPES OF ARTIFICIAL NEURAL NETWORKS.....	61
3.5.1	SINGLE LAYER NETWORKS	62
3.5.2	TWO LAYER NETWORKS	62
3.5.3	MULTI LAYER NETWORKS	62
3.6	CURRENT APPLICATIONS OF ARTIFICIAL NEURAL NETWORKS	64
3.6.1	FORECASTING OR PREDICTION.....	64
3.6.2	IMAGE RECOGNITION	66
3.6.3	TEXT PROCESSING	66
3.6.4	OPTIMIZATION	67
3.7	ADVANTAGES OF ARTIFICIAL NEURAL NETWORKS OVER CONVENTIONAL STATISTICAL METHODS.....	67
3.7.1	LESS NEED TO DETERMINE RELEVANT FACTORS A PRIORI.....	68
3.7.2	SOPHISTICATION OF THE MODEL	68
3.7.3	DIRECTNESS OF THE MODEL	68



3.7.4	FAULT TOLERANCE.....	69
3.7.5	INHERENT PARALLELISM	69
3.8	LIMITATIONS OF NEURAL NETWORKS	70
3.9	SUMMARY.....	71
4	<u>RESEARCH METHODOLOGY</u>	<u>72</u>
4.1	INTRODUCTION	72
4.2	AIMS OF RESEARCH.....	72
4.2.1	MAIN AIM	73
4.2.2	SUB AIMS	73
4.3	RESEARCH DESIGN.....	74
4.4	SUBJECTS.....	74
4.4.1	CRITERIA FOR THE SELECTION OF SUBJECTS	75
4.4.1.1	Hearing Ability.....	75
4.4.1.2	Middle Ear Functioning.....	77
4.4.1.3	Attention Span.....	79
4.4.1.4	Criteria Regarding subject Age and Gender	79
4.4.2	SUBJECT SELECTION PROCEDURES	80
4.4.2.1	Case History and Personal Information	81
4.4.2.2	Otosopic Examination.....	81
4.4.2.3	Tympanometry	82
4.4.2.4	Traditional Audiogram	82
4.5	APPARATUS	83
4.5.1	SUBJECT SELECTION APPARATUS	83
4.5.2	DATA COLLECTION APPARATUS.....	84
4.5.3	DATA PREPARATION APPARATUS	84
4.5.4	DATA ANALYSIS APPARATUS	84



4.5.5	PRELIMINARY STUDY.....	85
4.5.5.1	Determination of Subject Selection Criteria	85
4.5.5.2	Determination of Optimal Stimulus Parameters.....	87
4.6	DATA COLLECTION PROCEDURES.....	89
4.6.1	DATA COLLECTION PROCEDURES IN THE SELECTION OF SUBJECTS.....	90
4.6.2	DATA COLLECTION PROCEDURES CONDUCTED DURING RESEARCH.....	90
4.6.2.1	Data Obtained From Pure Tone Audiometry	90
4.6.2.2	Data Obtained from DPOAE Measurements	91
4.7	DATA PREPARATION PROCEDURES	96
4.7.1	CREATION OF A DATA FILE FOR EACH EAR	96
4.7.2	SELECTION OF THE TYPE OF NEURAL NETWORK	98
4.7.2.1	Selection of the Topology of the Neural Network	99
4.8	DATA ANALYSIS PROCEDURES.....	110
4.9	SUMMARY.....	112
5	<u>RESULTS</u>	<u>114</u>
5.1	INTRODUCTION	114
5.2	SCENARIO THREE: PREDICTION OF AVERAGE HEARING ABILITY.....	115
5.2.1	THE PREDICTION OF AVERAGE HEARING ABILITY IN THE SEVEN 10DB CATEGORIES	116
5.2.2	THE PREDICTION OF AVERAGE HEARING ABILITY IN THE FIVE CATEGORIES....	119
5.3	PREDICTION OF 500 HZ.....	121
5.3.1	THE PREDICTION OF 500 HZ IN SCENARIO FOUR.	121
5.3.2	PREDICTION OF 500 HZ IN SCENARIO FIVE.	125
5.4	PREDICTION OF 1000 HZ.....	127
5.4.1	PREDICTION OF 1000 HZ IN SCENARIO FOUR.....	128
5.4.2	PREDICTION OF 1000 HZ IN SCENARIO FIVE.	130

5.5	PREDICTION OF 2000 HZ	132
5.5.1	PREDICTION OF 2000 HZ IN SCENARIO FOUR.....	132
5.5.2	PREDICTION OF 2000 HZ IN SCENARIO FIVE.....	134
5.6	PREDICTION OF 4000 HZ	136
5.6.1	PREDICTION OF 4000 HZ IN SCENARIO FOUR.....	137
5.6.2	PREDICTION OF 4000 HZ IN SCENARIO FIVE.....	139
5.7	SUMMARY OF RESULTS AT 500, 1000, 2000 AND 4000 HZ	141
5.8	THE EFFECTS OF AGE AND GENDER ON THE DISTORTION PRODUCT	144
5.8.1	THE EFFECT OF GENDER.....	147
5.8.2	THE EFFECT OF AGE.....	148
5.8.3	THE EFFECT OF AGE AND GENDER COMBINED.....	149
5.9	SUMMARY OF RESULTS	153
<u>6 DISCUSSION OF RESULTS</u>		<u>155</u>
6.1	INTRODUCTION	155
6.2	INDICATION OF A CORRELATION BETWEEN DPOAE MEASUREMENTS AND PURE TONE THRESHOLDS	156
6.3	PREDICTION OF AVERAGE HEARING ABILITY	158
6.4	PREDICTION OF 500 HZ	160
6.5	PREDICTION OF 1000 HZ	164
6.6	PREDICTION OF 2000 HZ	167
6.7	PREDICTION OF 4000 HZ	169
6.8	CASE STUDIES WHERE THE AUDIOGRAM WAS PREDICTED ACCURATELY	171
6.9	CASE STUDIES WHERE THE AUDIOGRAM WAS PREDICTED INACCURATELY	173
6.9.1	INTERESTING PHENOMENA IN CASES PREDICTED INACCURATELY.....	174
6.9.1.1	Subjects Demonstrating Hearing Loss Due to Noise Exposure.....	174
6.9.1.2	Subjects Demonstrating Very Mild Hearing Loss.....	176



6.9.1.3	A Subject Demonstrating A Possible Retrocochlear Hearing Loss.....	176
6.10	VARIABLES THAT INFLUENCED THE OUTCOME OF THIS STUDY	177
6.10.1	VARIABLES OF THE DISTORTION PRODUCT OTOACOUSTIC EMISSION	177
6.10.1.1	Technical Parameters of DPOAE Measurements.....	178
6.10.1.2	DPOAE Analysis Variables.....	178
6.10.2	VARIABLES OF THE NEURAL NETWORK.....	181
6.10.2.1	Neural Network Topology	181
6.10.2.2	Amount of Data Available to Train on in Every Category.....	183
6.10.3	SUBJECT VARIABLES.....	186
6.10.3.1	The Age Variable.....	187
6.10.3.2	The Gender Variable.....	187
6.10.3.3	The Combination of the Age and Gender Variables	188
6.10.3.4	The Presence of a Spontaneous Otoacoustic Emission Close to the Distortion Product	189
6.11	DPOAE MEASUREMENTS AS A DIAGNOSTIC OR HEARING SCREENING PROCEDURE	190
6.12	THE EFFECTIVENESS OF THE APPLICATION OF NEURAL NETWORKS TO THE FIELD OF AUDIOLOGY.....	194
6.13	SUMMARY.....	195
<u>7 SUMMARY, EVALUATION OF THE STUDY AND CONCLUSION.....</u>		<u>197</u>
7.1	SUMMARY.....	197
7.2	EVALUATION OF RESEARCH METHODOLOGY	205
7.2.1	THE RESEARCH DESIGN	206
7.2.2	VALIDITY AND RELIABILITY	206
7.2.3	LIMITATIONS OF THE STUDY.....	210
7.3	RECOMMENDATIONS FOR FUTURE RESEARCH.....	212



7.4 GENERAL IMPLICATIONS OF THE STUDY AND CONCLUDING REMARKS 213

List of Tables

I	Time required testing one subject	89
II	The 11 frequency pairs tested by the GSI-60 DPOAE system when all four octaves are activated	92
III	Example of a data file for one DP Gram	97
IV	Seven categories of hearing ability for scenario three and four	105
V	The five categories of hearing ability for scenario five	107
VI	Example of the results of the neural network's prediction of 1000 Hz for 10 ears, (scenario four)	111
VII	Results of the neural network's prediction accuracy for average hearing ability for the seven 10dB categories	117
VIII	False positive and false negative responses for the prediction of average hearing at the seven 10dB categories	118
IX	Number of ears in the seven categories of scenario four for prediction of average hearing ability	118
X	Number of ears in the five categories of scenario five for the prediction of average hearing ability	119
XI	Results of the neural network's prediction accuracy for prediction of average hearing ability for the five categories of scenario five	120
XII	False positive and false negative responses for average hearing ability at the five categories of scenario five	121
XIII	Results of the neural network's prediction accuracy at 500 Hz for the seven 10dB categories of scenario four	123

XIV	False positive and false negative responses for 500 Hz at the seven categories of scenario four	123
XV	Number of ears in the seven categories of scenario four for 500 Hz	124
XVI	Number of ears in the five categories of scenario five for 500 Hz	125
XVII	Results of the neural network's prediction accuracy at 500 Hz for the five categories of scenario five	126
XVIII	False positive and false negative responses for 500 Hz at the five categories of scenario five	127
XIX	Results of the neural network's prediction accuracy at 1000 Hz for the seven categories of scenario four	128
XX	False positive and false negative responses for 1000 Hz at the seven categories of scenario four	129
XXI	Number of ears in the seven categories of scenario four for 1000 Hz	129
XXII	Number of ears in the five categories of scenario five for 1000 Hz	130
XXIII	Results of the neural network's prediction accuracy at 1000 Hz for the five categories of scenario five	131
XXIV	False positive and false negative responses for 1000 Hz at the five categories of scenario five	131
XXV	Results of the neural network's prediction accuracy at 2000 Hz for the seven categories of scenario four	133
XXVI	False positive and false negative responses for 2000 Hz at the seven categories of scenario four	133
XXVII	Number of ears in the seven categories of scenario four for 2000 Hz	134
XXVIII	Number of ears in the five categories of scenario five for 2000 Hz	135

XXIX	Results of the neural network's prediction accuracy at 2000 Hz for the five categories of scenario five	135
XXX	False positive and false negative responses for 2000 Hz at the five categories of scenario five	136
XXXI	Results of the neural network's prediction accuracy at 4000 Hz for the seven categories of scenario four	137
XXXII	Number of ears in the seven categories of scenario four for 4000 Hz	138
XXXIII	False positive and false negative responses for 4000 Hz at the seven categories of scenario four	138
XXXIV	Number of ears in the five categories of scenario five for 4000Hz	139
XXXV	Results of the neural network's prediction accuracy at 4000 Hz for the five categories of scenario five	140
XXXVI	False positive and false negative responses for 4000 Hz at the five categories of scenario five	140
XXXVII	Summary of the results for 500, 1000, 2000 and 4000 Hz for scenario four	142
XXXVIII	Summary of the results for 500, 1000, 2000 and 4000 Hz for scenario five	143
XXXIX	Prediction of average hearing ability with DPOAEs and gender	147
XL	Prediction of average hearing ability with DPOAEs and age	148
XLI	Prediction of average hearing ability with the combined effects of gender and age	149
XLII	Summary of the prediction of average hearing ability and the effects of age and gender on prediction accuracy	150

XLIII	Summary of the effects of age and gender on the seven 10dB categories of scenario four	151
XLIV	Subject information of cases predicted accurately	173
XLV	Subject information of cases predicted inaccurately	173

List of Figures

Figure 1.1: Schematic Diagram of a Representative System for Measuring TEOAEs	11
Figure 2.1: The spectrum of the ear canal sound pressure of a normal hearing adult undergoing DPOAE testing	20
Figure 2.2: Probe microphone system for distortion product otoacoustic emissions	22
Figure 2.3: Schematic representation of a system used to measure distortion product otoacoustic emissions	22
Figure 2.4: DP Gram of a normal hearing adult's right ear	27
Figure 2.5: I/O Function of a normal hearing adult	27
Figure 2.6: Scattergram of emission threshold versus auditory threshold as measured by Kimberley and Nelson, (1989)	42
Figure 3.1: A biological neuron	56
Figure 3.2: An artificial neuron	57
Figure 3.3: Inputs to several nodes to form a layer	57
Figure 3.4: Connection of several layers to form a network	58
Figure 3.5: Diagram of a back propagation neural network	63
Figure 5.1: Accuracy of the neural network prediction at 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz, scenario four	145
Figure 5.2: Accuracy of the neural network prediction at 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz, scenario five	146
Figure 5.3: Prediction accuracy of average hearing ability when the age and gender variable are included	152

Figure 6.1: Case studies where the audiogram was predicted accurately	172
Figure 6.2: Case studies where the audiogram was predicted inaccurately	175
Figure 6.3: Prediction accuracy and ear count correlation for scenario four	184
Figure 6.4: Prediction accuracy and ear count correlation for scenario five	185



List of Appendices

A: The interview

227

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