INPUT-OUTPUT FUNCTION OF DPOAE IN CHILDREN

REG. NO.M9616

An Independent Project submitted as part fulfilment of First Year M.Sc, (Speech and Hearing), Mysore.

All India Institute of Speech and Hearing, Mysore

May 1997

CERTIFICATE

This is to certify that this Indepedent Projec entitled **INPUT - OUTPUT FUNCTION OF DPOAE IN CHILDREN** is th bonafide work in part fulfilment for the degree of Master o science (Speech and Hearing) of the student with Registe NO.M9616.

Mysore
May, 1997

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CERTIFICATE

This is to certify that this Independent Project entitled **INPUT - OUTPUT FUNCTION OF DPOAE IN CHILDREN** has been prepared under my supervision and guidance.

Mysore
May, 1997

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DECLARATION

This Independent Project entitled INPUT - OUTPUT FUNCTION OF DPOAE IN CHILDREN is the result of my own study under the guidance of Mrs. Vanaja C.S., Lecturer in Audiology, All India Institute of Speech and Hearing, Mysore and has not been submitted earlier at any University for any other diploma or degree.

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INTRODUCTION

Hearing begins with pressure disturbances that enters our ears, and ends with auditory cortex. When sound impinges on the eardrum, the vibrations are transmitted to the oval window by the middle ear bones, which cause movements of cochlear fluids. This initiates a wave of displacement on basillar membrane which is very important stage in the analysis of sound by auditory system.

However, only recently has it been demonstrated that the ear, besides, receiving sounds, also produces sounds (Kemp, 1978). These sounds, emitted by the ear are called Oto-acoustic emission (OAE).

OAE represent an objective measurement of the active micromechanical function of outer hair cells of the inner ear. Information of preneural mechanical elements of the cochlea can be obtained by means of OAE.

By arranging OAEs according to the type of stimulus that elicits them, 2 distinct classes can be distinguished. The emission that is spontaneously present without any external stimulation, called spontaneous otoacoustic emissions.

whereas emission evoked by different kind of acoustic stimulation is called evoked otoacoustic emissions.

I Spontaneous Otoacoustic Emission (SOAE)

SOAEs are continuous narrow band signals emitted by about 50% of human ears even in the absence of external acoustic stimulation. They range in amplitude from about -25 dB SPL upto 20 dB SPL, with majority falling between -10 and +10 dB SPL (Wilson and Sutton, 1981).

II Evoked Oto-acoustic Emissions

Evoked emissions can be divided into 3 subclasses depending on the type of eliciting stimulation.

a) Transient evoked otoacoustic emissions

Transient evoked otoacoustic emissions also referred to as click evoked OAE (EOAEs) are frequency dispersive responses following a brief acoustic stimulus, such as a click or a tone burst (Kemp, 1978). TEOAEs are measurable in essentially all normal hearing persons with normal middle ear and normal cochleas (Kemp, 1978, Martin and Lonsbury-Martin, 1986).

b) Distortion product otoacoustic emission

DPOAEs are result of interaction of two simultaneously presented puretones (the primaries). In human, the most prominent DP is the cubic difference tone (Kemp, 1979).

Manipulation of primaries give rise to two concepts.

(1) Distortion product audlogram/DPgram

Here frequencies are changed while level is kept constant. Distortion product audiogram does not include the concept of threshold. It supplies information across a wide frequency range but usually at one or 2 levels.

(2) Input-Output functions

In this procedure, frequency is kept constant while level is changed, it will result in i/p - o/p functions. I/p -o/p functions provide information about threshold, maximal amplitude or saturation point (growth behaviour of ADPs) of DPOAE.

c) Stimulus frequency emissions

Acoustic stimulation with a low-level constant tone lead to generation of additional acoustic energy from cochlea at the frequency of stimulation. These emission were called stimulus frequency emissions (Kemp and Chum, 1980).

DPOAE represent one type of evoked emission that has significant potential for becoming an important list in the audiometric evaluation of hearing capacity (Lonsbury-Martin, 1986) . First advantage is the objective responses that can be measured non-invasively with only passive to cooperation of the subject (Bray and Kemp, 1987). It does not need any skin preparation (for application of electrodes) since responses can be measured by placing a small mic in the outer ear canal. Thus, conveniently used for measuring hearing acuity of young children including neonates.

Time taken to test a patient using DPOAE may vary with exact procedure used for measurements. But it takes shorter test time (mean: 12.1 min) compared with ABR method (mean: 21.0 min) (Stevens et al. 1989). Since it takes less time and has straight forward application, it has potential use in testing difficult to test population.

Another major advantage is that DPOAE can givehighly precise frequency specific information. Since DPOAE are emitted at a known frequency, related to the stimuli, it helps in determining exact place on the basilar membrane (Anova. et al. 1993).

The high sensitivity and specificity of DPOAE to the status of the cochlea represents an important advantage. There are indications that even subtle changes of cochlea function that may not result in changes in puretone audiogram can lead to significant changes in DPOAE (Kemp, 1988). Thus DPOAE testing have capability of delimiting quite accurately, the boundary between normal and abnormal function. In cases in which the etiology of a discrete hearing loss is unknown, the degree of association between the pattern of DPOAE measured, diminished activity of OHC and configuration of hearing proficiency, represented by standard audiogram can establish the diagnosis of a sensory versus or a more general SN deficit (Lonsbury-Martin and Martin, 1990).

Compared to other evoked emissions types, the reasonably wide dynamic range of DPOAEs in terms of growth of response amplitude as a function of stimulus level, permits a complete evaluation of cochlear function at both threshold and suprathreshold levels of stimulations. This features allows the use of DPOAE to study remaining OHC functions in the ears of patients demonstrating hearing loss upto 45 to 55 dB HL.

In contrast, TEOAEs cannot typically be measured in individuals with hearing loss > 30 dB HL (Lonsbury-Martxn and Martin, 1990). To determine the dynamic range of distortion -generation process, the input output function are generated over a 60 dB range of stimulus level. From these curves, details concerning the function of the give OHC at either threshold or suprathreshold sound levels can be determined.

One of the evaluation of I/O functions demonstrated reduced DPOAE in response to high freuquency stimulation at 5 and 8 KHz, even though the results of audiometric examination suggested the diagnosis of normal hearing. These findings support that DP I/O evaluation may detect some early symptom of OHC damage. Since DPOAE selectively test OHC functioning (Lonsbury-Martin and Martin, 1990).

I/O function of DPOAE also has ability to reflect temporary improvements in cochlear function with Meniere's disease (Lonsbury-Martin and Martin, 1990). DP thresholds provide reasonably good estimates to tho hearing loss in cases where primary damage to OHC can be safely assumed Eg. NIHL. A relatively strong relationship existed between DP threshold and majority of hearing loss (Lonsbury-Martin and Martin, 1990).

Several studies have shown significant age related changes in the otoacoustic emission. Characteristics of DP emissions as a function of age was also studied and studies have shown that DP emissions decrease as age increases (Lafreniere et al. 1991; Lasley, Perlman and Hecox, 1992; Norton, Bargones and Rubel, 1991; Rahul, 1996; Yasmeen, 1996).

Age effects were also studied in other types of OAE. Findings reported in literature generally agree that TEOAE are detected in normally hearing infants or children in proportions that are similar to that observed in adults (Steven et al. 1987; Johnsen et al. 1988). Further, the amplitude of TEOAE in children may be larger than under comparable conditions in adults (Bray and Kemp, 1978), and the main frequency components maybe higher (Johnsen et al. 1989; Kemp et al. 1990).

The above studies shows that there is a significant age related changes in the oto-acoustic emission. Since distortion produce oto-acoustic emissions, represent one type of evoked emission that has significant potential for becoming an important test in the audiometric evaluation of hearing capacity, a study was undertaken to investigate the input -output function in the children, age ranging from 4 to 7 years.

Studies done on age related changes of DP detection threshold on subjects with age ranging from 21-30 years (Lonsbury-Martin and Martin, 1990) and 31-60 years (Lonsbury-Martin and Martin, 1991) showed that DP detection threshold increased on age increased.

This present study was undertaken to investigate whether there is any change in detection threshold as a function of age in children population.

AIM OF THE STUDY

- To study the input-output functions of distortion product otoaocustic emission in children in the aim to -
  - Obtain the detection threshold of DPOAB.
  - Growth behavior of DPOAE and level at which amplitude saturates.
- To compare the amplitudes of DP emission and detection threshold in children across the age in order to ascertain if there is any significant difference between the group on age increases.

REVIEW OF LITERATURE

The ear had always been considered as a passive organ with a well-defined function of receiving and transducing acoustic energy until 1948, when Gold proposed the hypothesis that the sharp frequency selectivity exhibited by the cochlea is a resulted from a feedback system consisting of mechanical to electrical transduction process.

Discovery of OAE by Kemp in 1978 changed the general view of the ear as a passive receptor organ to a very complex organ with bidirectional properties. He demonstrated that energy was emitted by cochlea and that it was recordable as acoustic vibrations in ear canal using specialized methods and technique. Yet another breakthrough was when Kemp (1979) reported evoked OAEs in response to a transient stimulus such as click or tone bursts. The presence of evoked sound that was measured in ear canal provided direct evidence of the existence of active mechanical mechanisms within cochlea.

Cochlear origins of OAE

The emissions were believed initially to be an artifact, possibly related to ME activity. Much of earlier evidence demonstrating the cochlear origin of OAE came from studies showing that agents known to damage the cochlea reduced or eliminated OAE. Additional evidences supporting the cochlear origin come from studies investigating the effects of ototoxic drugs on various emission types. Such drugs are tonix to cochlear structures and their ingestion has been shown to lead to reduction in, or elimination of OAE (Anderson and Kemp, 1979; Kemp and Brown, 1984).

In the animal studies, although the effects of acoustic overstimulation have been documented on various types of emissions, the most thoroughly studied OAE is the DPOAE.

The DPOAE originates due to non-linearlity in the cochlea, which leads to a distortion of the stimuli (Hall, 1974). In humans, Brown and Kemp (1984) showed that 2fl-f2 DPOAE are generated at the cochlear partition or at the site of primary frequencies or at the site of f2 formation.

Brown (1987) opined that origin of DPOAE varies with the intensity of evoking stimuli. Low level highly vulnerable distortion products associated with active cochlear process, thought to be based on the micro mechanics of OAE, whereas less vulnerable high level distortion product may be associated with passive, micromechanical properties of cochlear partition (Drown, 1907). DP generated by primary frequencies at intensity below 60 dB SPL (i.e. the saturating portion) probably have their origin in the properties of OHC. If intensity exceeds 60 dB SPL (i.e. linear portion), it is probable that only passive properties of the cochlea are main contributor to observed distortion products (Brown, 1988).

Helmholtz (1870) thought that this distortion was generated in the most obvious mechanical system, the middle ear. Wever (1940) confirmed that distortion in the auditory system can be generated by overdriving the mechanical conduction system at excessively high levels. Goldstein (1967) provided the Ist clear evidence of the inner ear locus for generation of distortion products.

Many other studies (Kemp and Brown, 1983; Brown et al. 1989; Martin, et al. 1988) have generally assumed that the origin and the vulnerability of DPS is more linked to mechanical interaction between the places corresponding to fl and f2. This view is supported by clinical observations showing that audiometric threshold for fl and f2 influences the amplitude of DPS much more than the audiometric threshold of 2fl-f2 frequency.

Experiments done on animals show that the stereocelia are the primary force generators that provide OHCs mechanical contribution to the nonlinear processes of cochlear (Monntain and Hubbard, 1989). Investigations done by Horner et al. (1985), Katz et al. (1989), Brown et al. (1989) demonstrates that intact mechanical and/or electrical connections between IHC and OHC are necessary for the generation of robust DPOAEs.

Prevalence of DPOAEs

Majority of studies (Kemp, 1978; Rutter, 1980; Zwicker, 1983; Bonfils, et al. 1988) reports that EOAE prevalence is 90-100% in normal hearing. This value drops with an increasing amount of hearing loss (Johnsen et al. 1983; 1988; Elberging, et al. 1985). EOAE prevalence in high risk babies in intensive care amounts to 79-81% (Steven et al. 1987; 1989).

DPOAE are relatively strong and easy to record in common lab animals. Although DPOAE are much of smaller amplitude in human ears, the distortion product at frequencies 2fl-f2 can be detected in almost all normal hearing ears (Probst et al. 1991).

In animals, probably the 1st DPOAEs were reported by Kim et al. (1980) in the cat. Robust DPOAEs that was relatively easy to record were detected in many common laboratory animals.

2fl-f2 DPOAE which have been described for the chinchilla (Zureket al. 1982) and rabbit (Lonsbury-Martin, Martin et al; 1987), whereas DPOAES at 3fl-2f2 have been measured systematically only in rabbit (Lonsbury-Martin et al. 1987). In all these animals, DPOAEs are reliably recorded provided that both hearing and ME function were normal.

Kemp et al. (1986) reported DPOAE in all 14 normal ears they examined and Lonsbury-Martin et al. (1990) in all 44 ears from 22 normally hearing individuals. These findings indicate that DPOAEs can be recorded in well over 90% of normal ears. The frequency range within which acoustic distortion products are reliably detected is between 1 and 8 KHz with reference to geometric mean of fl and f2 stimuli (Martin, et al. 1990). Acoustic distortion product are generally absent in ears with sensory neurally loss greater than about 50-60 dB (Lonsbury-Martin and Martin, 1990).

Characteristics of DPOAE

DPOAE are emissions due to interaction of 2 tones, separated in frequency by a given number, presented simultaneously. The emission is neither of the 2 stimuli frequency but another tone related to the stimuli (Kemp, 1978). The most commonly observed DP frequency is seen at a point given by the formula 2fl-f2 where fl and f2 are 2 stimulus tones such that f2 > fl (Lonsbury-Martin et al. 1986).

In discussing distortion products, the stimulus frequencies traditionally are called primary frequencies (fl < f2 < f3, etc.) and intensity of the stimulus, levels of the amplitude of DPOAE is dependent on the amplitude of the primary stimuli (Kemp, 1980) . The variability of DPOAE has been measured over a period of weeks and has been found to be 5 to 9 dB, depending on stimulus conditions but not the individual amplitude of response (McLoy, et al. 1990). In addition, DPOAE can be recorded reliably in the region of 6-8 KHz (Roede, et al. 1991).

Input-Output Function of DPOAE

Distortion products are measured on *2* protocols they are DPgram and input-output function. In input-output function, a series of responses are determined at GM that are related to the conventional audiogram (1-8 Khz) by varying the primary tone level in 5 or 10 dB steps. Several quantitative features of emitted responses can be determined from the resulting curves, including detection threshold, maximum amplitude, dynamic range, slopes which relates the rate at which emission grows as a function of increased primary tone levels (Lonsbury-Martin and Martin, 1991).

DP I-0 function typically has 2 separate portion (1) a saturating portion between DP detection threshold and the stimulus level around 60 dB SPL *12)* steeper linear portion for stimulus level above 60 dB SPL. Rate of growth of around 1 dB/dB for low level stimulus was seen, but then saturated for stimulus level greater than about 50 dB SPL (Bonfils, et al. 1994).

A study done by Nelson and Kimberley (1992); Popelka et al. (1993) showed that there was a gradual plateau for signal levels between 40 and 60 dB SPL. DP T-0 function for low level signals in neonate produce some results as there in normal adults. Valid measures were obtained for very low stimulus levels (as low as 30 dB SPL).

DP at 2fl-f2 grow slightly steeper slope of 1-5 per dB increase in primary tone levels. For stimulus level of 70 dB and above a slowing of growth of DP magnitude was observed for the 2fl-f2 DP. However a similar non-linearity was not evident for 2f2-fl DP atleast upto 75 dB SPL (Lonsbury-Martin, Probst and Loat, 1987).

A study done on rat by Marlenoir and Puel (1987) showed that the dynamic range of the response vs. the increased level of primaries is generally comprised between 15 and 25 dB SPL and response tend to saturate for high levels of stimulus tones. The response often exhibit a plateau in the middle of the curves (Kim, 1980; Humes, 1980).

Wit and Ritsma (1979), Rutten (1980) found that I-0 function of the peak-peak amplitude of the response are non-linear and saturation appears at higher intensities.

In small mammals, the systematic growth of 2fl-f2 DP amplitude with increase stimulus levels often show non-linear monotonicities ranging from shallowing of the slope to complete loss of emission, within a narrow range of stimulus levels (Kim, 1980; Zurek, et al. 1982). For stimulus levels well below 60 dB SPL, the growth function is determined by the output of low level source only. For level above 70 dB, growth function is determined by high level source (Kim, 1980).

Study done by Schloth (1982) and Wilson (1980), reported the following that the growth rate were often non-monotonic at intermediate level, where magnitude of DP leveled off. There were sharp notches in i/o function at particular primary tone frequency between 1.4 and 2-8 KHz. For both 2fl-f2 and 2f2-fl these critical slope varied from 0-4 to 1.3 dB/dB averaging around 0.8 dB/dB irrespective of primary tone frequency. Somewhat higher slope between 2 and 3 KHz of 2fl-f2 measured are related to the fact that threshold near 2 KHz is especially low. At primary tones levels exceeding the plateau notch region (50-60 dB SPL) £-0 function tended to growth at much faster rate.

Lonsbury-Martin and Martin (1990) reported that *$-0* slopes of DP at low level in bobtail lizard's ear canal are near or below 1 dB/dB, at least for equal level primary tones. In humans, the I-*0* slope for equal level primary tone are 0.91 dB/dB (Gaskill and Brown, 1990). But they seem to be frequency dependent ranging from 0.4 dB/dB at low frequencies and about 1 dB/dB at high frequencies (Lonsbury-Martin and Martin, 1990).

A study done by Nelson and Kimberly (1992) showed that in mammals the growth of 1/0 function varied with frequency. At 1 and 2 KHz the growth was linear between 30 and 50 dB, with slope of 1.3 and 1.4 dB/dB respectively. At 4 KHz, the i/o function grew linearly upto 60 dB with slope of 1.05 dB/dB. The growth in amplitude near more gradual at the higher level, sometimes reaching plateau. At 8 KHz, the growth, in amplitude was linear across the entire range of levels with slope of 1.32 dB/dB.

Lonsbury-Martin et al. (1990) studied 1-0 function in SN hearing loss patients, found that T-0 function became more liner with a steeper slope. It was also found that hearing threshold above 30 dB HL also became liner without any saturating portion.

DPOAE threshold are defined as the I/p level at which the DP is at a criterion level (eg. 3 dB) above the noise floor (Lonsbury-Martin and Martin, 1993).

Several studies have provided evidence that DP-detection threshold measures derived from DP-growth function may be an useful indication of status of cochlea (Wilson, 1980 ; Schloth, 1982; Wier, et al. 1988). It has been reported that detection threshold ranged from 30-70 dB SPL in normals and were typically higher in frequency region with known SN hearing loss (Kimberley and Nelson, 1989; Lonsbury-Martin et al. 1990; Leonard et al. 1990 and Martin, et al. 1990).

Manley and Kopp (1993) observed that the area of greatest sensitivity fell between 1 and 2 KHz for both 2fl-f2 and 2f2-fl, considering only the threshold values at respective optimal primary tone and frequency ratio. In addition, the absolute threshold values and range of DP detection threshold closely resemble the values in range of neural threshold. For low frequency primary tones (Fl < 1005 KHz), the threshold of DP detection were quite variable between individual. Threshold for higher frequency primary tones were more consistent.

Detection threshold for DPOAE depends almost entirely on noise floor and sensitivity of the measuring equipment (Lonsbury-Martin et al. 1990).

Various investigations has been done to study about the variations on amplitude of DPOAE as a function of frequency and intensity.

In common laboratory animals, DPOAE amplitudes were of 30-40 dB less than stimulus level (Kim, et al. 1980; Whitehead et al. 1991). It was noticed that DPOAE amplitude varied with stimulus level.

In a study done by Gaskill and Brown (1990), it was noted that amplitude of DPOAE (LDP) varied according to stimulus level variation. The variations used in the study were

(LI and L2 are levels of the primaries)
L1 - L2 = -10
L1 - L2 = -5
L1 - L2 = 0
L1 - L2 = 5
L1 - L2 = 10

They found that stimulus level dependent effects on LDP were less obvious when L1 was held stationary. They concluded that LDP was more dependent on L1 than on L2. They also noted that highest LDP was obtained L1-L2 condition. LDP was affected more for negative L1-L2 them positive L1-L2 values.

Study done by Rasmnssen et al. (1993) also showed similar results. LDP gradually increased as the negative L1-

L2 values approached zero, and the rate of reduction of LDP in relation to negative value of L1-L2 was substantially greater at higher frequencies. AT 6-8 KHz, DP amplitude were at least 5 dB above the noise floor, for input level of 35 dB and higher. At 5-6 KHz, their response were above the noise floor even at input level of 5 dB SPL.

The result of detailed studies in rabbit further showed that the optimal L1-L2 decreases with increase in stimulus intensity (Whitehead et al. 1990). Because of lack of composite knowledge concerning the testing of DP in humans, the levels of primaries are typically equated (L1=L2) and restricted to < 90 dB SPL (Harris, 1990; Kimberly and Wilson, 1989).

The single most important variable for discrimination of normal hearing from hearing-impaired status is the DP amplitude at 60 dB SPL (L1) for the frequency associated with the predicted puretone threshold (Kimberly, et al. 1995).

Variables affecting DPOAE

Variables affecting the DPOAE responses in humans can be classified into, the factor related to test which consist of primary tones (Lonsbury-Martin et al. 1990), the relative level of the primary tone (Schloth, 1982) and other procedural factors and other being the factor related to subject like integrity of ME (Lonsbury-Martin et al. 1990). Integrity of cochlea (Kimberly and Nelson, 1989); Age (Lonsbury-Martin et al. 1991).

Test related variables

1) Stimulus level : The amplitude of distortion products is dependent on the amplitude of the primary stimulus (Lonsbury-Martin et al. 1986). Study done by Gaskill and Brown (1993) showed that acoustic distortion generated by relatively low stimulus level can be measured from the adult ear. DP generated stimulus level of 60 dB SPL and below showed saturating growth (Bonfils, et al. 1994). DP elicited by low levels {< 60 dB SPL) stimuli display a differential dependence in stimuli parameter to those evoked by high level (>60 - 70 dB SPL) stimuli, indicating the differences in the underlying generating mechanism (Whitehead et al. 1992). The physiological vulnerability of these DPs in rodents is level dependent, such that the DP evoked by low level stimuli (<60 - 70 dB) considerably more susceptible to trauma than those evoked by high level stimuli (Norton and Rubel, 1990).

Brown (1987) observed that DP evoked by low level primaries disappeared very rapidly upon induction of anoxia and showed no recovery. DPs-evoked by high level primaries demonstrated a much slower time course (Brown, 1987; Norton and Rubel, 1990).

At low level, DP grows at rate of 1 dB/dB in adult humans (Popelka, Osterhammel, Rasmussen, 1993). For higher levels, the measurements likely are influenced by process that may not involve OHC system exclusively. But for low level signals upto 60 dB SPL, the measurement presumably reflect metabolically active non-linear cochlear process associated with OHC (Mills, Norton and Rubel, 1992, 1993). A compounding factor is that the cochlear process of concern are associated more with processing of low level signals (Dalls and Martin, 1994).

For stimulus well below 60 dB SPL, Gaskill and Brown (1990) suggests that DP measurements using low level stimulation could form the basis of an objective measure of cochlear function in human subjects.

DP elicited by primary stimulation with intensity of 72 dB SPL do not permit sensitive test to separate the subject with hearing level above or below 30 dB HL (Martin, et al. 1986). DP emission elicited by primary stimulation intensity of 42 dB SPL permit obtaining a sensitive test. But specificity of the test is reported to be poor. DP elicited by primary intensity of 52 and 62 dB SPL permit obtaining most sensitive test. Best results reported were to be obtained with primary stimulation level around 52 dB SPL (Bonfils and Avans, 1992).

In conclusion, the levels of fl compared to f2 have been less thoroughly examined human ears. However findings in animals (Wiederhold, et al. 1986; Whitehead et al. 1990) and other theoretical consideration suggest that primary level are most effective when fl is 5-10 dB greater than f2 i.e. (L1 > L2).

(2) Frequencies

A study by Gorga et al. (1993) compared the TEOAE and DPOAE responses. It was observed that there was better performance at and below 1000 Hz for TEOAE compared to DPOAE. But at and above 4 KHz, DPOAE responses were better. Poor low frequency responses were attributed to 2 causes (1) Ambient room and breathing noise which consist of low frequency energy and (2) Middle ear may transmit less energy. Both in forward and reverse direction at lower frequencies.

Lonsbury-Martin and Martin (1991) studied DP level for 6-8 KHz region tended to be lower for older subjects. DP were detectable for all the subjects from 5-8 KHz. At around 1300 Hz, there was a small elevation where a maximum DP were seen which were 6-12 dB SPL for children and 2-9 dB SPL for adults. Study done by Sanders et al. (1983) indicated that occurrence of growth of DP level was highest in 2.8 and 4 KHz bands.

The ME transmission and cochlea ability to produce distortion are relatively constant across the frequency range of 1000-8000 Hz. DP data for lower frequencies were characterized both by higher threshold and lower amplitude for suprathreshold. However noise levels were not likely to influence amplitude for higher level primaries where larger S/N ratio was achieved (Gorga, et al. 1993).

Probst and Harris (1989) studied the growth function of DP in frequency region of 1, 2, and 4 KHz. The growth function of DP were not significantly steeper at 1-2 KHz, but became steeper at 4 KHz.

3. Frequency ratios l£2/£l)

Frequency separation of the primary tones is a principle factor in determining DP amplitude.

Previous studies have suggested that an f2 :fl ratio around 1.2 results in the highest amplitude of 2fl-fl DP. f2 :fl ratio reported as optiminal in humans were 1.22 (Harris, et al. 1989; Bonfils, et al. 199..) and 1.23 (Gaskill and Brown, 1990).

Study done by Nielsbn, Popelka and Rasmussem (1993) compared the DP responses by varying f2:fl ratio from 1.15 to 1.40. The results showed that DPOAE were discriminable above the noise floor in all ears at all test frequencies and amplitude was consistent between 1.20 and 1.25 at most frequencies. Lator studies showed that maximum DP amplitude for low frequency emissions were evoked with larger (1.26) f2/fl values and at relatively high stimulus level, whereas the largest high frequency DP were noted for smaller (1.19) f2/fl ratio when low level primaries were used (Wilson, 1980).

Primary tones when situated in the most sensitive frequency range extending from 5-6 KHz to 11.3 KHz, the optimal ratio of f2 to fl was 1.25. However for frequencies in lesser than 5-6 KHz, a separation of fl and f2 that was slightly greater was needed to produce 30 dB SPL emission (Humes, 1980).

Subject variables

(1) DPOAE and puretone thresholds

Initial studies done on TEOAE shows that ear associated with puretone threshold of less than roughly 30 dB HL generally produced an emission (Bonfils et al. 1988) .

Many studies have been done on DPOAE which shows correlation between the 2fl-f2 DP detection threshold and hearing threshold at the frequency corresponding to the Geometric mean (Martin et al. 1988; Lonsbury-Martin and Martin, 1986; Gaskill and Brown, 1990).

First as reported by Kimberley and Nelson (1989) and Lonsbury-Martin and Martin (1990). There is a high correspondence of DP threshold with PTT. DP threshold appears to provide the most consistent correspondence with audiometric contours. A general equation to describe relationship between ADP level and auditory sensitivity has been derived by many others (Kimberley and Nelson, 1989; Probst and Hanser, 1990). But the complex dependence of ADP levels on stimulus level would not allow an equation desired at one particular level to predict threshold from ADP measures at other stimulus level (Gaskill and Brown, 1990). And other variables like differences in ME transmitter characteristics, presence of strong emitting cochlear region or spontaneously emitting cochlear region make it unrealistic to use general equation to predict auditory threshold (Gaskill and Brown, 1990).

The DPE features such as DPE amplitude for stimulus level of 65-75 dB SPL correlate well with puretone threshold at associated frequencies (Lonsbury-Martin and Martin, 1990). According to Gaskill and Brown (1990), the presence of DP that are produced by high level stimuli may not correspond well with hearing sensitivity. DP generated with lower level puretone may approximate audiometric results more closely. Leonard (1990) also showed that DP threshold in normal hearing subjects occur at or below levels of 60-65 dB SPL for equal primaries.

Many studies has shown variation of DP amplitude which correlates with variation in audiometric thresholds. DP amplitude decreases as audiometric threshold increases at least upto audiometric threshold of 25 dB which is consistent with the observation at 4 KHz and 8 KHz (Gorga, Bergman, 1993).

Kemp et al. (1986) reported DPOAE measurements in ears with high frequency hearing losses. In these cases, the DPOAE amplitudes were significantly smaller than normal values at frequencies where hearing thresholds were better than 30 dB HL. In another study of DPOAE, Harris (1990) reported systematic results with high frequency hearing loss. His study showed that if hearing thresholds at predetermined frequencies were better than 15 dB HL, DPOAEs were always detected. However, emissions were absent or attenuated if behavioural threshold exceeded 50 dB HL.

Harris (1990) describe the relation between DP threshold, amplitude and audiometric threshold in 20 normals and 20 hearing-impaired. Results showed subjects with hearing loss typically had higher DP threshold and lower amplitude responses. However, Allen and Lewitt (1922), showed that measurements can distinguish normal and hearing-impaired subject for higher frequencies, once the hearing loss exceeds about 20 dB HL.

In many studies it has been suggested that absence of emissions always indicate a moderate to severe hearing loss (Bonfils and Uzeil, 1989; Probst, et al. 1990). Emissions are reduced or absent in cochlear hearing loss of at least 30 dB HL (Kemp et al. 1986) or even 15 dB (Collet and Morgan, 1991; Prost et al. 1990).

The accuracy with which DP measurements identify hearing loss as a function of frequency still remains undetermined (Harris, 1990). Correlation between hearing loss, amplitude and threshold suggest that performance will be poorest in low frequencies (Martin et al. 1990) .

Effect of external ear

Pressure on the ear canal was found to have a slight influence on the spectral content of the response. At ambient pressure a typical response would be distributed about a median frequency of 1.7 KHz,. With increase in positive or negative pressure, frequencies in the spectrum were systematically displaced to higher frequencies of approximately 1.5 Hz/dapa (Gilman and Dirks, 1980).

When using DP probe, distance of speaker source tube from eardrum also has its effect (siegal, 1994). In adult, the frequency at which cancellation is greatest at DP probe mic varies greater across ears, but it is usually at 3.5 and 7 KHz. In contrast, near the eardrum, cancellation occurs at a frequency above those typically used in DP studies and has little effect on stimulus SPLs below 9 KHz.

Amplitude reduction with increasing age has been attributed to the small size of infant ear canal (Kok, et al. 1992).

Study done by Chavy and Lekas (1993) showed that the total number of ears passing OAE examination increases from 76% to 91% after debris was removed from the ear canal, thus debris can attenuate OAE signal. A larger improvement of 3.5 dB occurred in there ears.

Effect of ME

Experience with sound elicited emissions in both TEOAE and DPOAE, have to perform a 2 fold pass through the middle ear. This means the stimulus sound coming into the cochlea is highly dependent on the forward transfer function of the ME mechanism and this is also true for elicited emission on its retransmission to the ear canal. For these sound elicited emissions, the loss in energy transfer will be 2 fold because the stimulus as well as the retransmitted emission will be affected by the less complaint ME system. Even very small pressure difference among tympanic membrane may change the size of EOAEs (Osterhammel, Nelsen and Rasmnssen, 1983).

The emission level of OAEs is greatest at ambient ear canal pressure. The rate emission level decreases as a function of ear canal pressure. Previous investigation have reported that emission level increases at a constant rate (in dB/dB) for levels ranging from 0-20 dB. And at much slower rate at higher levels (Kemp, 1978).

Wada, Ohyama and Koike (1995) studied relationship between frequency of DP and resonant frequency of middle ear and relationship of DP level and ME mobility. The highest DP level were detected at primary F2 frequency higher than 5 KHz. Before measurements it was expected that the DP level would be largest when cubic distortion frequency 2fl-f2 coincident with middle ear resonant frequency.

Comparing the DP measurement result with those of ME frequency characteristics, it is revealed that the drastic increase in the DP level at primary f2 frequency lower than 1 KHz after tympanic bulla perforation and following upward primary f2 frequency shift of DP peak level with an increase in the diameter of the hole were coincident with resonant and shift of ME due to manifestation of the tympanic bulla.

DPOAE level was largest at primary frequency around 1.2 KHz with nearly considered with resonance frequency of middle ear. DP level decreases with an increase in primary f2 frequency upto 3 KHz then increase upto 8 KHz. Afterwards, the DP level decrease sharply with increase in the frequency.

DP amplitude is affected rather more by negative ear canal pressure (5 dB/100 dapa), than by +ve ear canal pressure beyond 100 dapa tend not to affect the DP amplitude (Osterhammel, Nelson, Rasmussu, 1933).

Presence of SOAE

Kok (1994) suggest that large prevalence of SOAE is one of the reasons for the high level of TEOAE on healthy newborns. Even in preterm neonates, ears with SOAE had a statistically larger amplitude than ears without TBDAEs (Bonfils, et al. 1992).

In human data, the o/p of DP is strongest when the DP rather than primary tones lies at the frequency of a strong spontaneous emission (Wilson, 1980; Wit, et al. 1981). Wier et al. (1986) found DP near the original frequency of the SOAE to be still larger by 10 to 20 dB than they were 100 Hz away from this region. For any given DP stimulus situation, the likelihood that the frequencies of fl/f2 or DP correspond closely to the known frequency of SOAE was quite large.

Moulin et al. (1992) reported that in humans DP show high frequency amplitude and lower detection threshold when recorded in the vincity of an SOAE and SOAE can affect the position of notch in DP 1-0 function. The primary levels increase, SOAE amplitude and frequency decrease DP response quickly disappear into the noise floor. DP 1-0 function present notches near the SOAE frequency, lower the primary level where the notch appears (Wilson, 1980).

Drugs

The influence of anesthesia on the acoustic response was highly variable and this was attributed to the changes in the middle ear pressure which are known to accompany inhalation of anaesthetic gases. Thus absence of detectable response in these circumstances may be an indirect consequence of anaesthesia rather than in duration of cochlear dysfunction (Robinson and Hanghton, 1991).

Growth rate of TEOAE and DPOAE was studied as a function of increased quinine concentration. Magnitude decrease was substantially larger for TEOAE than for DPOAE. DPOAE shift was less than the band pass filtered TEOAE response, although the typical growth rate for DPOAE was 0.7 -0.8 dB/dB below 75 dB SPL (Lonsbury-Martin, et al. 1990). The induced OHC pathology did not change DPOAE above 60 dB SPL, but a distinct reduction mean seen below 60 dB SPL.

The effects of anesthesia on DP amplitude are shown on rabbit. In all instances, regardless of the level of primary tones, no difference between pre and post anaesthesia state occurred for any of the DP responses (Brown, 1987).

Hypoxia and Anoxia

Changes in DP amplitude were seen within 10-20 minutes of turning of the artificial respiration. Hypoxia eventully resulted in the loss of DP 2fl-f2 produced by primary tones of low to medium levels. The recovery of DP amplitude was also quite rapid (Norton and Rubel, 1990).

DP evoked by very low level primaries disappeared very rapidly upon induction of anoxia and showed no recovery. The DPs evoked by high level primaries demonstrated a much slower time course. The extremely rapid decrease of low level DPs observed in Gebrils and Rabbit upon reduction of 02 supply (Brown,et21 1987) .

Gender difference

The results of number of survey studies have demonstrated that SOAEs are more common in females than in males. Specifically, there is a greater prevalence of SOAE in i.e. greater female subject possess SOAEs than incase of males (Strickl et al. 1985; Bilger et al. 1990). Females demonstrate greater tendency to possess emissions bilaterally than do males.

In the study done by Yasmeen (1996) on 54 subjects age ranging from 50 days to 28 years. It was seen that younger group (below 8.11 yers), females showed higher TEOAE emission than males. However, in a study done by Lonsbury-martin and Martin (1990) on subjects age ranging from 21 years to 30 years, they found no significant difference in DPOAE emissionin males and female.

Age

Forward and reverse transmission is influenced by many properties, age being one of the important factor (Lafreniere et al. 1991).

In a variety of animal species, the development of inner ear preceds for a period after birth when both morphological and functional changes occur (Rubel, et al. 1984). In contrast, the human cochlea is generally thought to reach complete structural maturation in last trimester of pregnancy (Bredberg, 1968; Lavlque-Rebillard, 1987).

The ear canal continues to mature in child upto 7 years of age (Saunders, Kaltenbach and Relkin, 1983). Development of human cochlea, begin in the mid basal turn and progresses both apically and basally. It is complete by 32 weeks of RCA (Bredberg, 1968).

It is conceivable however, that functional changes may occur in a period after birth also, in the human organ of corti and that such changes may influence the evoked emissions (Saunders, et al. 1983).

Structural differences (anatomical) between children and adult has been quoted by many authors. In neonates, where the diameter of the canal is small and wall is complaint, the resonance gain is lower than that seen in adults (Saunder et al. 1983). Ear canal length in neonates is shorter than that of adult, and consequently has higher resonant frequencies (Bredberg, 1968).

Many functional differences as function of increase in age is also reported. Zimmerman et al. (1987) followed a group of normal infants from birth to 6 months of age and found that most significant change in response pattern took place during 1st 2 weeks of life. The emissions from the adult ear is highly stable and contains energy at preferential frequencies in response to different stimuli (Elbergling et al. 1985).

Distortion products obtained in neonates were quantitatively similar to those of adults. Stimulus spectrum in low frequency region was flat in adult but steeply attenuated in neonates, exhibiting stronger higher frequency spectral components in 4-6 KHz, than adults (Lafreniere et al. 1991).

Laskey et al. (1929), found average DP levels of 75 dB SPL in neonates, over a frequency range of 500 Hz to 10 KHz with f2/fl = 1.2 and primarily level of 65 dB SPL. This is only 2.5 do above the DP level evoked in adults.

The mean stimulus level of 80 and 82 dB SPL for newborn and adults respectively are comparable but the response levels in the new borns are significantly higher (22 vs 11 dB SPL). The reason suggested for this was may be small ear canal volume in new born (Bray and Kemp, 1987). In other study done by Lasley, Perlman and Hecox (1992), they found that DP data obtained for full term new borns and adult normal hearing) were at comparable levels except at high frequencies (9-10 KHz), adults 1-0 function were steeper than new born.

Norton, Bargones and Rulsel (1991) investigated the appearance and maturation of DPOAE with response to higher stimuli. The results showed that response appears 1st at 13-14 days after birth. Response to lower frequency did not appear until 18-19 days after birth and did not mature until one month of age.

However, result of study done by Jacek Smurzynski (1994) found that human active non-linear elements underlying DP generation function quite maturely in the 1-8 KHz region of cochlea at 33-34 week of PCA.

In neonates, the greatest amplitude were those generated by the primary tone when F2 was at 2 and 6 KHz. At these 2 peaks DP of 17.8 and 22.4 dB SPL respectively was generated (Marco and Morant, 1995). Smurzynski et al. (1993) reported about 20% of preterm infant ears without ME effusion had Es higher than 90th percentile of the full term newborn, mostly in 2.8 to 4 KHz region 69% exhibited DPOAE close to or higher than the top of normal range in 4 KHz region.

Many studies were conducted to investigate how DPOAE response change across the age. Several earlier studies were done using emission type including spontaneous and transiently evoked OAE. Bonfils (1989) determined that the prevelance of SOAE decreased progressively from 31 years to 50 years. Similarly, the results of the Bonfils et al. (1988) study of transiently evoked otoacoustic emissions in aging ears supports the finding of previous study. TEOAEs were detected in all subjects under 60 year old. A similar age related increase in emission detection threshold was identified in that, thresholds increased at a rate of approximately 7-10 dB for decade.

The systematic effects of aging on characteristics of i/o function was examined on subjects ranging from 31-60 years by Lonsbury-Martin et al. (1991). The influence of subjects age on DPOAE amplitude on a function of primarily tone level was that, aging systematically affected higher frequency emissions. There is a clear tendency for the oldest ears to generate smallest DPOAEs particularly at higher frequencies.

In the same study, they found age-related increase in detection thresholds. The results showed that frequencies that were expected to be most affected by the aging factor i.e. greater than 2 KHz thresholds increased about 0.5 -0.75 for year, over the 31 to 60 years age range and DP magnitudes decreased by about 0.3 dB especially for frequencies > 3KHz.

Robinette (1992) conducted on exhaustive study on age differences sequentially in dB SPL across age groups. It was found to vary as 9.7 for 20 to 29 year old group to 7.2 dB for 60 to 80 year old age group.

Norton and Widen (1990) summarized the finding with regard to developmental changes in TEOAE

(1) Amplitude reduces with age (Bray and Kemp, 1987).
(2) Energy spectrum tends to shift to lower frequencies (Kemp, Ryan and Bray, 1990).
(3) The latency tends to increase with age (Johnsen and Elberling, 1983).

Engdahl et al. (1994) conducted study of reproducibility of TEOAE in the 1st year life (at 3, 6 and 12 months). The amplitude was found to reduce with age.

In the study done by Yasmeen (1996) 53 subjects whose age ranged from 50 days to 28 years were tested for their age related changes.

The finding revealed the following:

(1) 100% occurrence of emission and the emission amplitude were below 0.0 dB in 11.63% of the ears.

(2) Emission spectrum became restricted in frequency with increasing age. The peaks in the wave form became widely spaced with increasing age.

(3) The average emission amplitude steadily decreased with age. But there is wide individual variability within age groups.

(4) Background noise levels steadily decreased with age.

(5) The mean amplitude were found to be -

14.98 -> 0 - 1.17 years
14.02 -> 3.0 - 5.11 years
7.46 -> 6.0 - 8.11 years

There is significant reduction of amplitude when passing from group II (3.0 - 5.11 years) to group III (6.0 - 8.11 years).

Martin et al. (1990) surveyed distortion product oto-acoustic emissions of 12 adults ranging in age from 21-30 years. One interesting finding uncovered in their normative study was that, the oldest individual exhibited high frequency deficits in DPOAE magnitudes. Thus, author suggested that the reduction in the amplitudes of the high frequency DPOPAEs and the concomitant increase in detection thresholds is due to aging effects. Moreover, it was also noted that across all the young subjects, DPOAE amplitude tended to decrease and detection threshold increase with age, for the 2 highest test frequencies at 6 and 8KHz. Both sets of findings concerning the relation of age to high frequency emissions suggested that acoustic distortion products may be highly sensitive to the effects of aging on cochlear function.

Further, DPOAE were examined with clinically normal hearing ranging in age from 31 to 60 years by Lonsbury-Martin et al. (1991). Their study showed that, DPOAE audiogram depicting emission amplitude in response to constant level stimuli, on a function of frequency, showed that BPOAE magnitude decreased in an orderly manner (as age increased) above 2 KHz. The i/o function which displayed DPOAE amplitudes as a function of primary tones levels, also demonstrated a progressive increase in detection threshold in a systematic decrement in response magnitudes, as a function of age.

DPOAE represents the functional activity of OHC system. DPOAE has been reported to be sensitive to detect age induced alterations to the OHC of aging humans with hearing levels within the range considered tobe clinically normal (i.e., better than 20 dB HL). It is necessary to establish valid distinction between the effect of normal aging compared tothe pathological process on cochlear function. Above studies

* have reported age related changes with reference to the DPOAE in older group. Also studies using other type of emission (TEOAB) have shown age-related changes in young groups (Bonfils et al. 1990; Norton and Widen, 1990; Yasmeen, 1996). This study was taken up with a principle aim to study the age-related ages of input-output function in DPOAE in children age ranging from (4-7 years).

METHODOLOGY

This study was takenup with an aim to establish input - output function of distortion product otoacoustic emission and estimation of detection threshold in children.

Subjects

A total of 30 subjects were takenup for this study. These subjects were in the age range of 4 - 7 years, grouped as Group I - 4-5 years; Group II 5-6 years; and Group III 6-7 years.

Criteria for selection of subjects

1. Subjects should have puretone thresholds of less than 25 dB HL in the frequency range of 250 Hz and 8000 Hz.

2. Subjects should have 'A' type tympanogram and acoustic reflexes should be present.

3. Subjects should not have any known otological problems or h/o otological problems.

Instruments

1) Pure tone audiometer

A 2 channel clinical audiometer Madsen OB 822 with TDH 39 earphones with MX-41/AR ear cushions was used to assess the behavioral thresholds of all the subjects. It was calibrated to study as per the recommendation of ANSI (1969).

2) Immittance evaluation : A screening Immitance Siemens Hand tympan 23002 was used to assess the middle ear functions of the subjects.

3) DPOAE Measuring System

The DPOAE measuring system called Bio-logic Scout DPOAE system with software version 1.1, was used for the purpose. The system allows for the user specifications to be used in testing for a number of parameter. With reference to the study, the following values were set up.

Display type

The display was set to input - output function. Setting plot the distortion products emission level in Y-axis, as a function of equilevel stimuli delivered from 70 dB to 0 dB in 10 dB steps.

L1 and L2 Levels

This refers to the intensities of the stimulus. In this study, L1 and L2 (Intensities of the primaries) was kept equal. DPOAE were tested at the primary levels (LI and L2) ranging from 70 to 0 in 10 dB steps at 2fl-f2 DPOAE frequencies.

Frequencies of the primaries

The amplitude of 2fl-f2 were determined in frequency region 1000 Hz, 2000 Hz, 4000 Hz and 8000 Hz.

Table-3.1: Frequencies and geometric mean of 2fl-f2 of the stimulus primaries.

Fl (Hz)	F2 (Hz)	GM (Hz)
415	488	450
855	1025	936
1660	2002	1823
3296	3955	3610
6665	8008	7306

For convenience, in the study, lOOOHz, 2000 Hz, 4000 Hz and 8000 Hz is used.

f2/fl ratio

Ratio determines the frequency separation of the 2 primaries. So far, the research has reported that maximum distortion is produced at f2/fl ratio of about 1.22. hence f2/fl ratio of 1.2 was used.

S/N ratio

It is one of the criteria for determining when to stop averaging. The ratio of DPOAE level to noise level was set to + 3 dB.

Token buffer size

This was set to 2048, which is at default setting.

TEST ENVIRONMENT

The tests were carried out in a sound treated room where the ambient noise level measured was with in specified limits. The test room had adequate lighting and was at comfortable temperature.

The subjects were provided with a comfortable chair to sit on during the test. They were not required to do any task.

TEST PROCEDURE

All volunteers were tested for their puretone thresholds in both ears using a 2-channel clinical audiometer (Orbitor-922). The frequencies tested were 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz and 8000 Hz. Any volunteers with thresholds greater than 25 dB HL at any frequency were rejected.

Subjects who had thresholds within 25 dB HL were then tested for tympanograms and reflexes in both ears. Only subjects with A-type tympanogram and acoustic reflexes were tested further.

Subjects who fulfilled both these criteria were studied for their distortion product otoacoustic emission. The test consisted of 3 phases which was done in the following order.

(1) **Check fit**

The probe was fitted and subjects were institute not to move. A transient stimuli was presented to the ear and the measured responses was displayed as a spectrum and waveform. If a correct waveform (as shown in fig.) was not obtained, then probe was taken out, checked for debris and refitted. The 'check fit' phase was redone.

(2) Calibration

In this phase, the stimulus sources were calibrated. The system response of each of 2 loud speakers necessary to provide the stimulus were measured and displayed. If the 2 responses overlapped, then it is indicated that the system is calibrated. (Fig. see in 51 (a) and 51 (b).

(3) **Measurement**

In this, stimuli were presented and DP emissions were measured. Two primary tones fl and f2 were generated by 2 channel frequency synthesizer and were mixed acoustically. DPOAE 1-0 function were generated for primary levels varying from 70 dB to 0 dB in 10 dB steps. The 2fl-f2 amplitude was plotted in dB SPL in Y-axis as a function of the intensities of primaries in X-axis, thereby obtaining input-output functions. Amplitude of 2fl-f2 and amplitude of noise floors were determined for each levels of the primaries. This

Figure 1

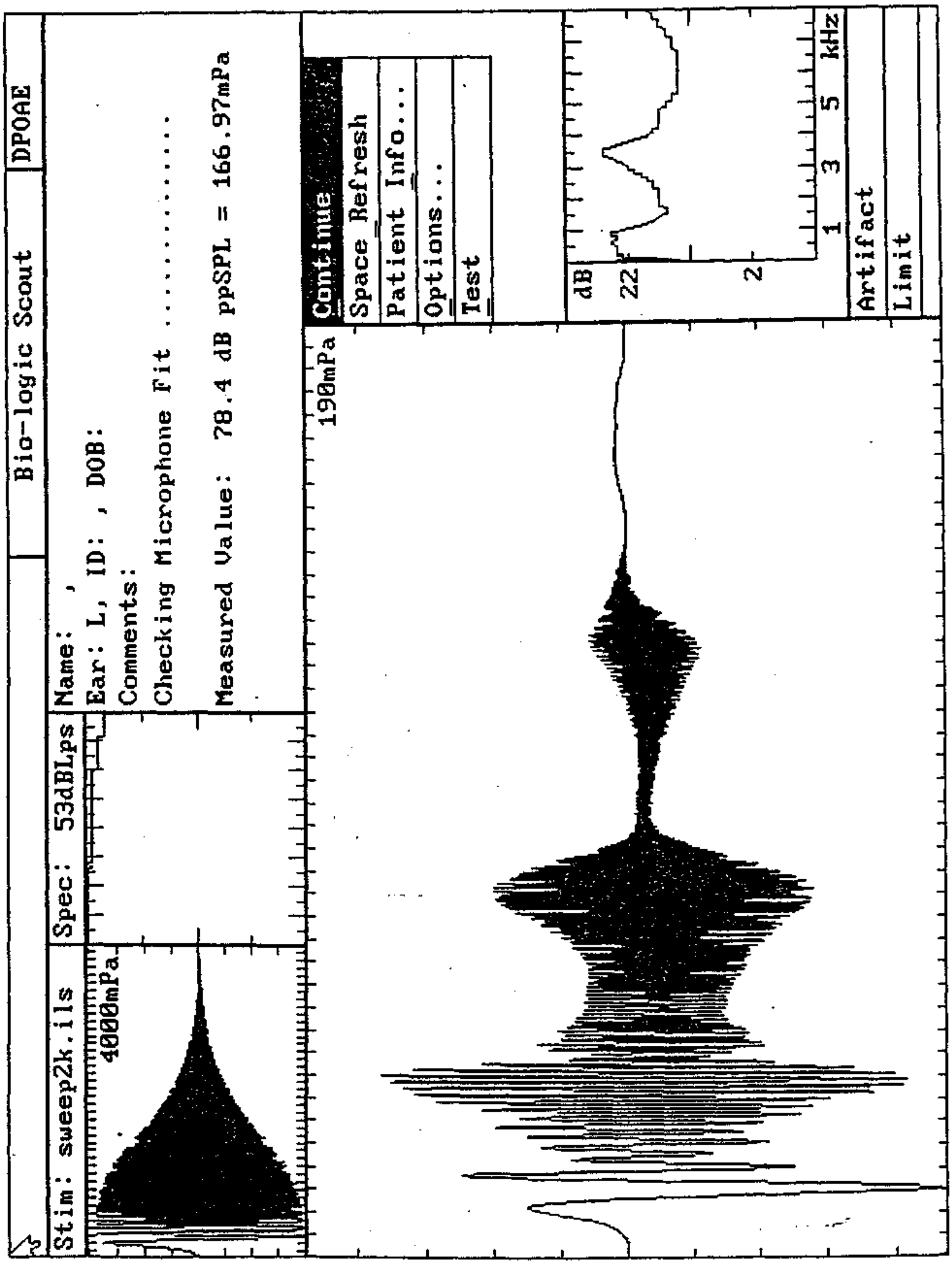
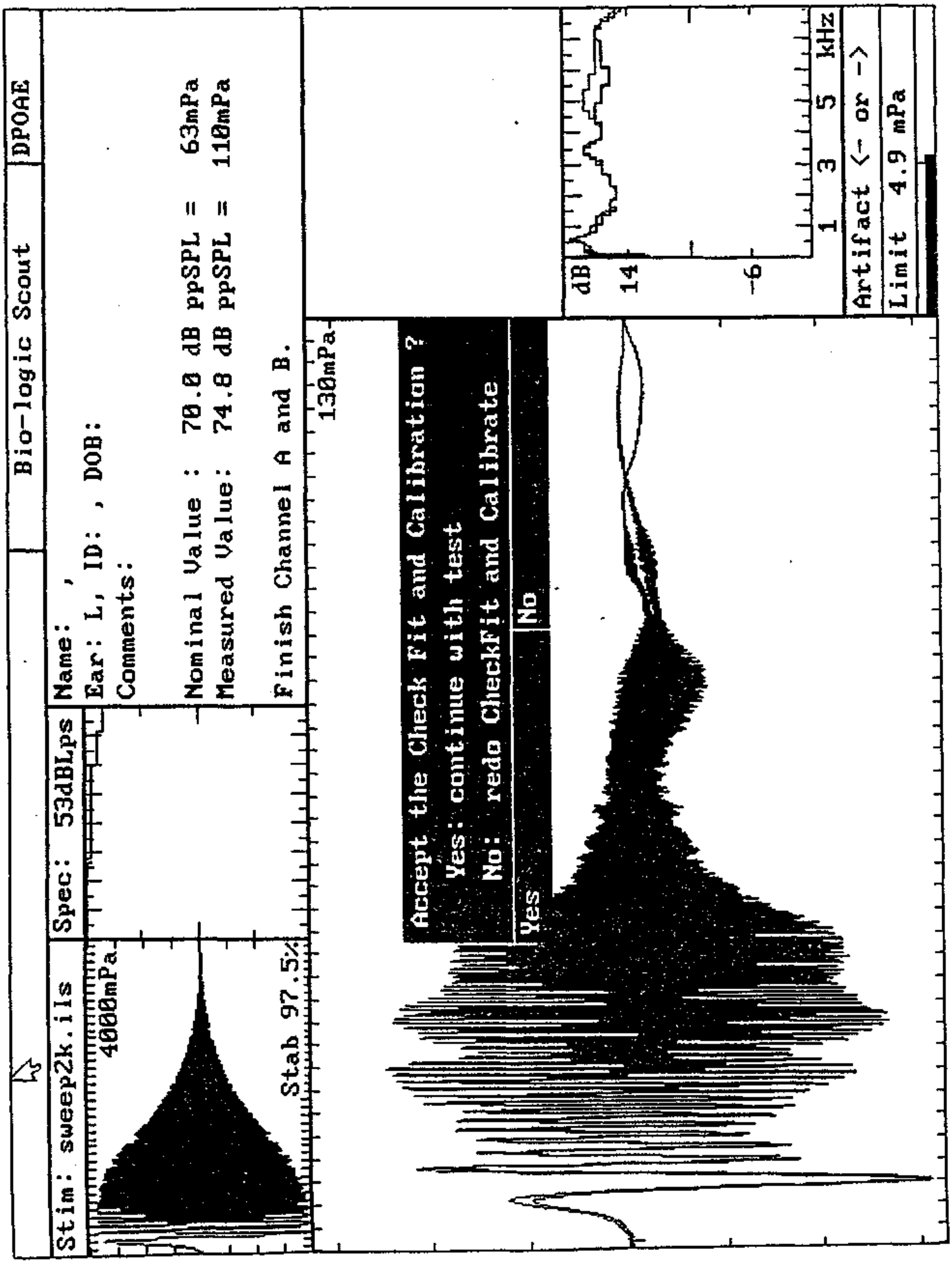

Bio-logic Scout
DPOAE
Stim: sweep2k.ils
Spec: 53dBLps
4000mPa
Name: ,
Ear: L, ID: , DOB:
Comments:
Checking Microphone Fit ....
Measured Value: 78.4 dB ppSPL = 166.97mPa
190mPa
Continue
Space Refresh
Patient Info...
Options...
Test
dB
22
2
1
3
5
kHz
Artifact
Limit

Figure 2


Bio-logic Scout
DPOAE
Stim: sweep2k.ils
Spec: 53dBLps
Name: ,
Ear: L, ID: , DOB:
Comments:
Nominal Value : 70.0 dB ppSPL = 63mPa
Measured Value: 74.8 dB ppSPL = 110mPa
Finish Channel A and B.
4000mPa
Stab 97.5%
130mPa
Accept the Check Fit and Calibration ?
Yes: continue with test
No: redo CheckFit and Calibrate
Yes
No
dB
14
-6
1 3 5 kHz
Artifact <- or ->
Limit 4.9 mPa

procedure was carried out for frequencies 1500 Hz, 2000 Hz, 4000 Hz and 8000 Hz.

Statistical analysis

The parameters considered are the intensities of primaries, amplitude of the DPOAE at a given frequency and the DPOAE detection threshold. They were obtained for frequencies 1000 Hz, 2000 Hz, 4000 Hz and 8000 Hz statistical techniques were then applied to determine if there is any significant difference existed between 3 age groups. The statistical procedure used included calculation mean and standard deviations. The procedures used for comparing the DPOAE in children across the 3 age groups involved using the 't' test of significance.

RESULTS AND DISCUSSION

Input-output function of DPOAE was studied at frequencies 100 Hz to 8000 Hz in 30 children in the age range of 4 years to 7 years. Group I (4-5 years), Group II (5-6 years), Group III (6-7 years).

Maximum Amplitude

Mean, SD and range of the DPOAE amplitude with stimulus level at 70 dB Hz was obtained for 3 groups across frequencies from 1000 Hz to 8000 Hz.

Table-4.1: DPOAE amplitude with stimulus level at 70 dB HL (L1-L2 = 70 dB HL) for children with age range 4-5 years.

Frequency (Hz)	Mean (dB)	SD (dB)	Range (dB)
1000	5.04	2.9	3.1 - 12.0
2000	12.3	4.6	4.5 - 14.5
4000	28.1	9.5	10.9 - 40.7
8000	19.94	9.2	10.4 - 37.8

Table-4.2: DPOAE amplitude with stimulus level at 70 dB HL (L1-L2 = 70 dB HL) for children with age range 5-6 years.

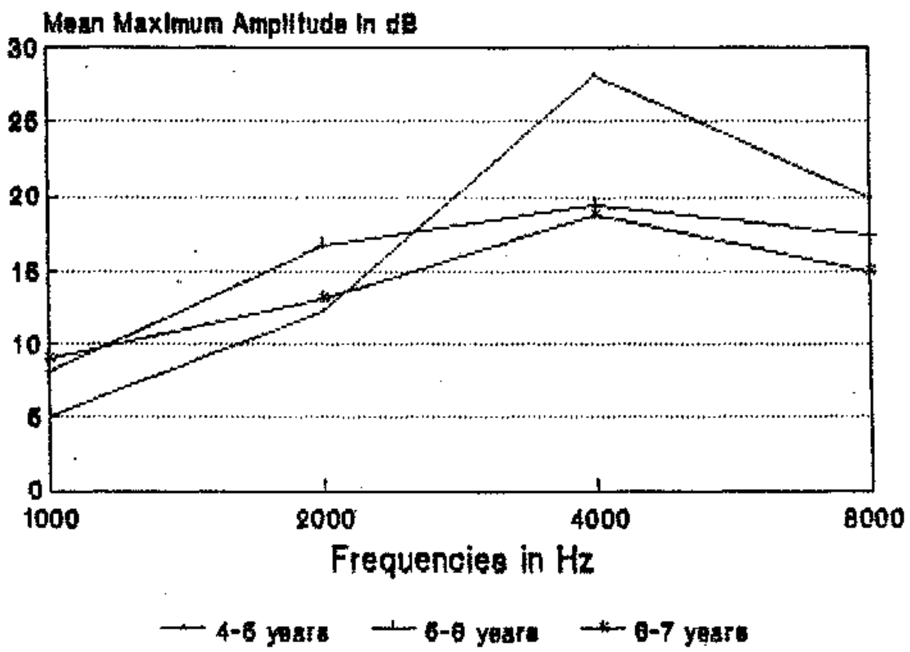
Frequency (Hz)	Mean (dB)	SD (dB)	Range (dB)
1000	8.16	8.9	-7.5 - 16.9
2000	16.74	7.57	6 - 20.8
4000	19.4	6.9	-4.2 - 28.0
8000	17.36	8.3	9.1 - 34.1

Table-4.3: DPOAE amplitude with stimulus level at 70 dB HL (L1-L2 = 70 dB HL) for children with age range 6-7 years.

Frequency (Hz)	Mean (dB)	SD (dB)	Range (dB)
1000	9.06	5.4	2.2 - 18.0
2000	13.1	4.8	4.3 - 19.4
4000	18.66	6.6	8.1 - 30.3
8000	15.04	4.1	9.8 - 22.5

It is noticed from the table (7, 8 and 9), there is a steady increase in maximum amplitude with increase in frequency from 1000 Hz to 8000 Hz, with a peak at 4000 Hz.

Gr.4,1;Maximum Amplitude for 3 groups across frequencies

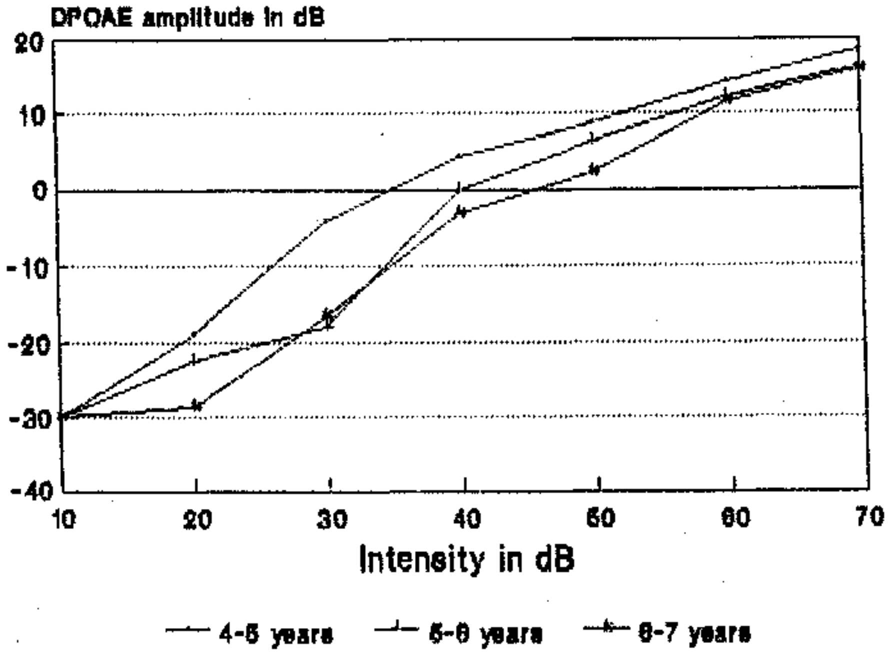


It is also noticed that mean maximum amplitude decreases as age increases. The amplitude decreased from Group I (4-5 years) to Group (III) (6-7 years) in all the frequency region except for 1000 Hz. The amplitude at 1000 Hz sees to deviate from the trend. A drastic decrease in the amplitude at 1000 Hz in Group I when compared to Group II and Group III. This decrease can be attributed to the increase in the noise floor level. The noise floor decreased from -12.67 to -26.7 as age increased in 1000 Hz region. A study done by Rahul (1996) on 30 children (age range 2 to 12 years, mean age 7.7 years) shows a similar Increase in noise floor at low frequencies. It was seen that DPOAE at low frequencies especially at 1000 Hz and 500 Hz were equal to or less than noise floor levels.

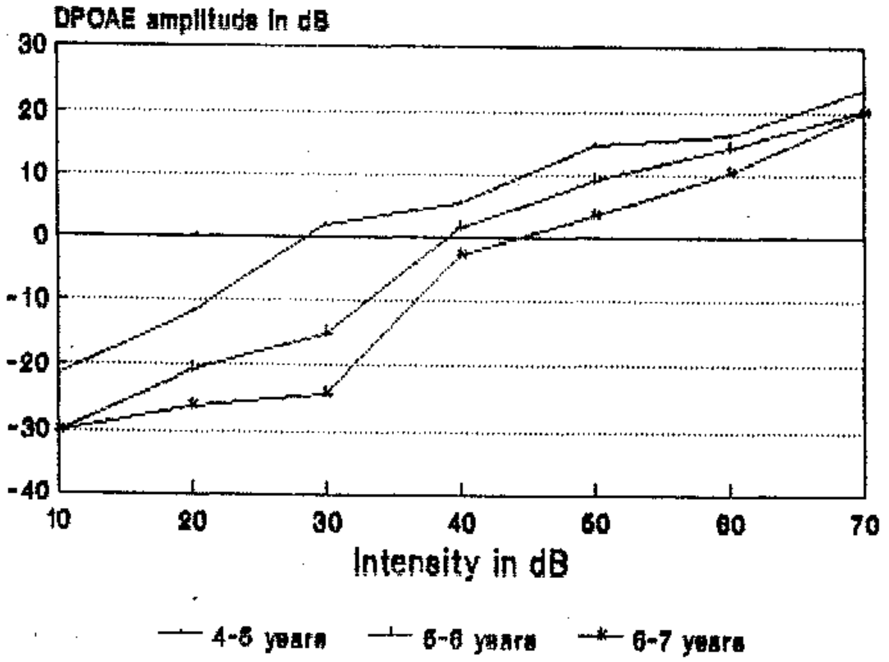
In other frequency region, the increase in maximum amplitude in younger age Group (4-5 years) can be attributed to small ear canal volume. In the study done by Feign, Kapin and Stelmachowicz (1989), it was found that infants and younger children (upto 5 years) had higher ear canal sound pressure level when compared to older group (age range 6-12 years). t-test of significance revealed that thre is no statistically significant difference in terms of maximum amplitude across frequencies.

On application of t-test of significance it was seen that there was no significance difference between males and females in terms of maximum amplitude.

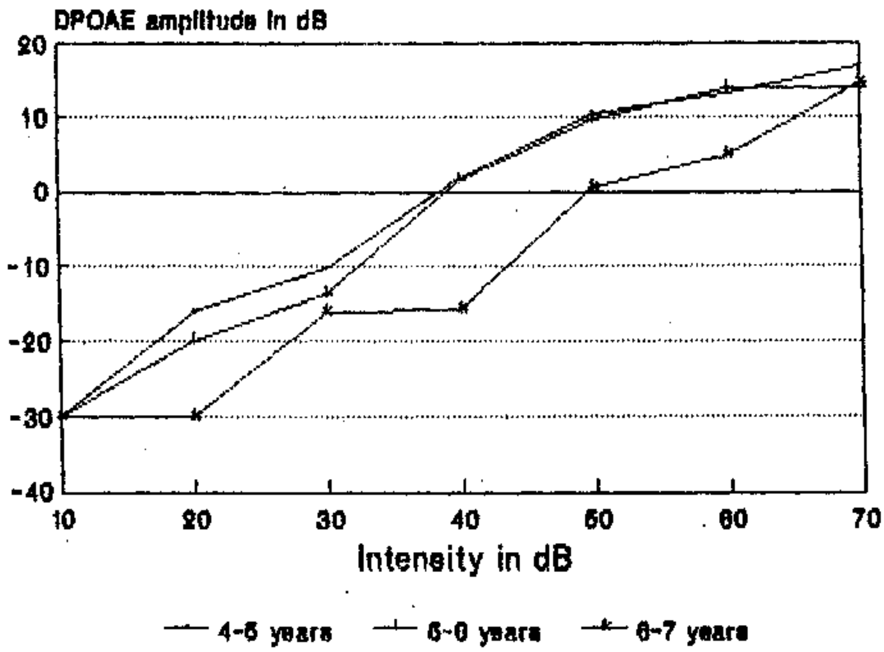
Gr.4.2: I/p & O/p slop for 3 groups for 8000 Hz



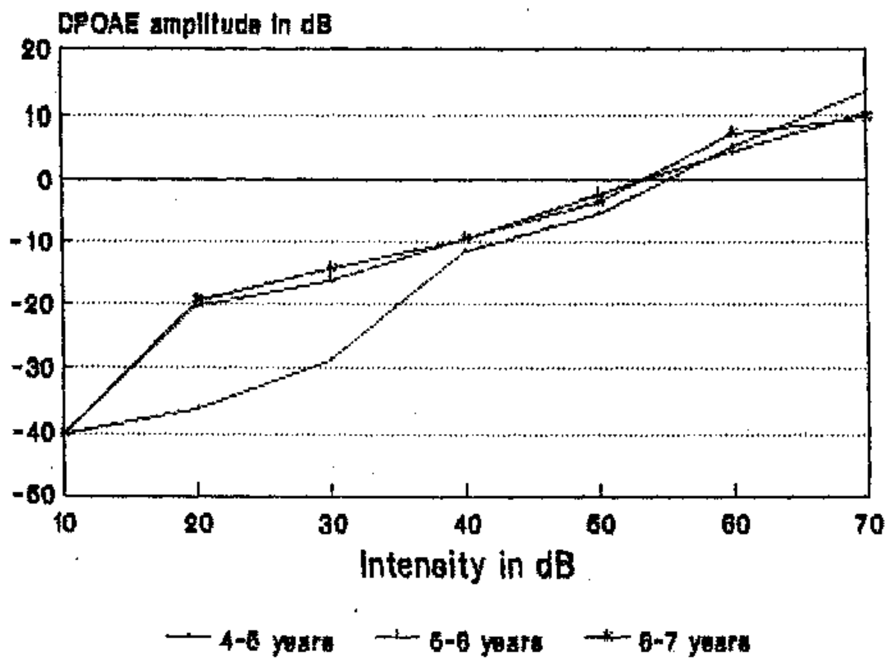
Gr.4.3: I/p & O/p slope for 3 groups for 4000 Hz



Gr.4.4:I/p & O/p slope for 3 groups
for 2000 Hz



Gr.4.5:I/P & O/p slope for 3 groups
for 1000 Hz



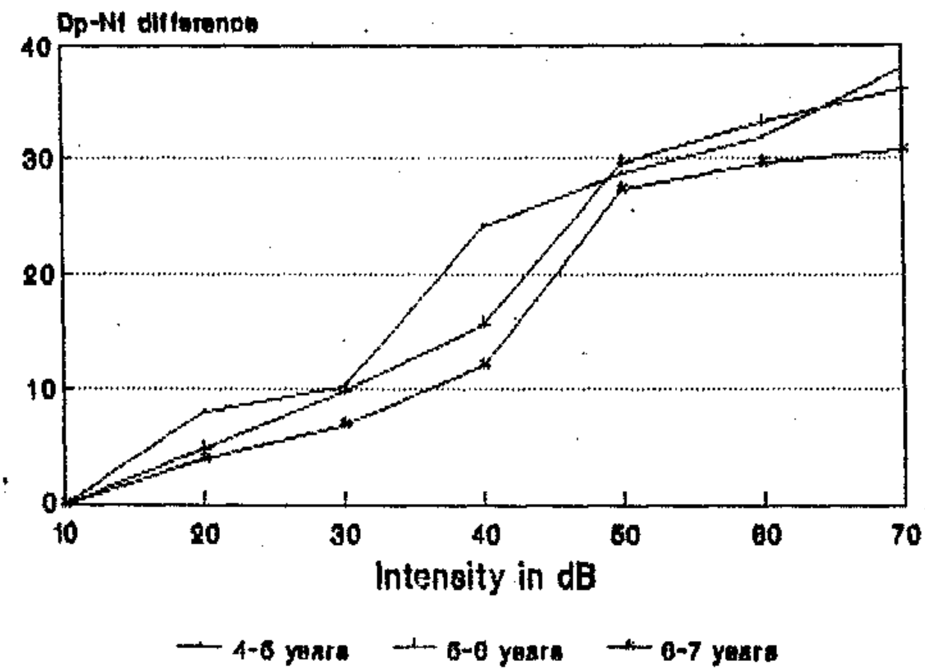
Slope

Intensity increased, the amplitude of DPOAE increased. From the graphs (4.2 to 4.5), it was noticed, that this trend is true for all the frequencies. In a similar study done by Lonsbury-Martin et al. (1990) on subjects age ranging from 21 to 30 years and by Lonsbury-Martin et al. (1991) on subjects age ranging from 31 years to 60 years, it was found that there is a steady increase in DPOAE amplitude as the intensities of primaries increased. In a study done by Rahul (1996), on 30 children age ranging from 2 to 12 years, DPOAE amplitude obtained at 50 dB HL and 70 dB HL was compared, it was seen that higher mean level of DPOAE, was obtained for higher intensities i.e. at 70 dB, consistently for all the age groups.

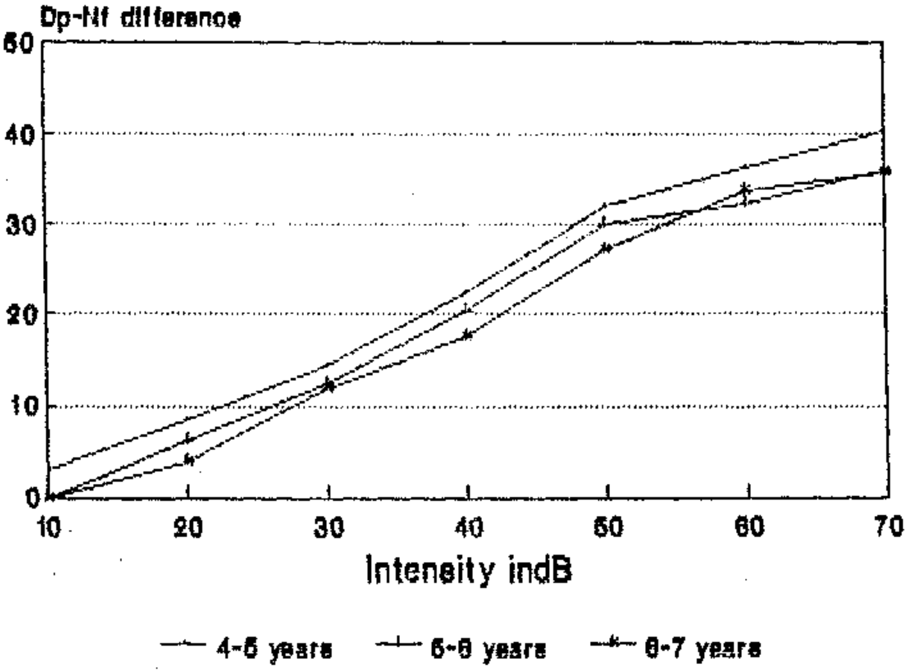
The rate of growth for low level stimulus was more compared to high level stimulus. In Graphs (4.2 to 4.5), it is noticed that growth was steeper for low level stimulus, slope became shallower as stimulus level increased from 50 dB SPL similar results have been reported by Kimberley and Nelson (1992) and Popelka et al. (1993). In their studies, they found a gradual plateau for signal level between 40 and 60 db SPL. In a study by Lonsbury-Martin et al. (1990) on his subject age ranging from 21 to 30 years, observed that there is slowing of growth of DP magnitude for stimulus level 60 dB and above.

It was also noticed that there was no statistically significant differences between males and females across all frequencies.

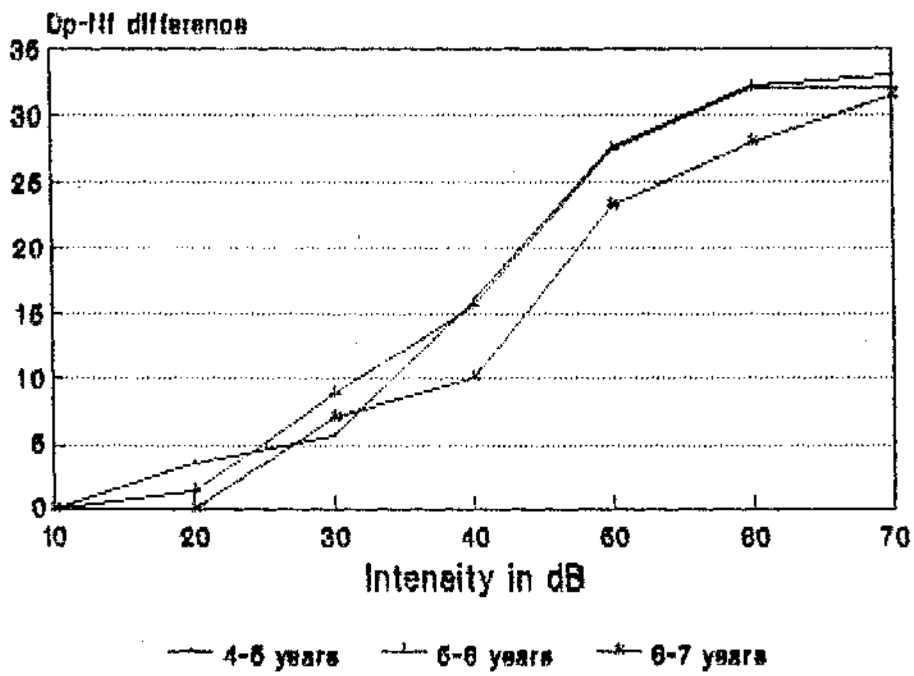
Gr.4.6:Dp-Nf differences for 3 groups at 6000 Hz

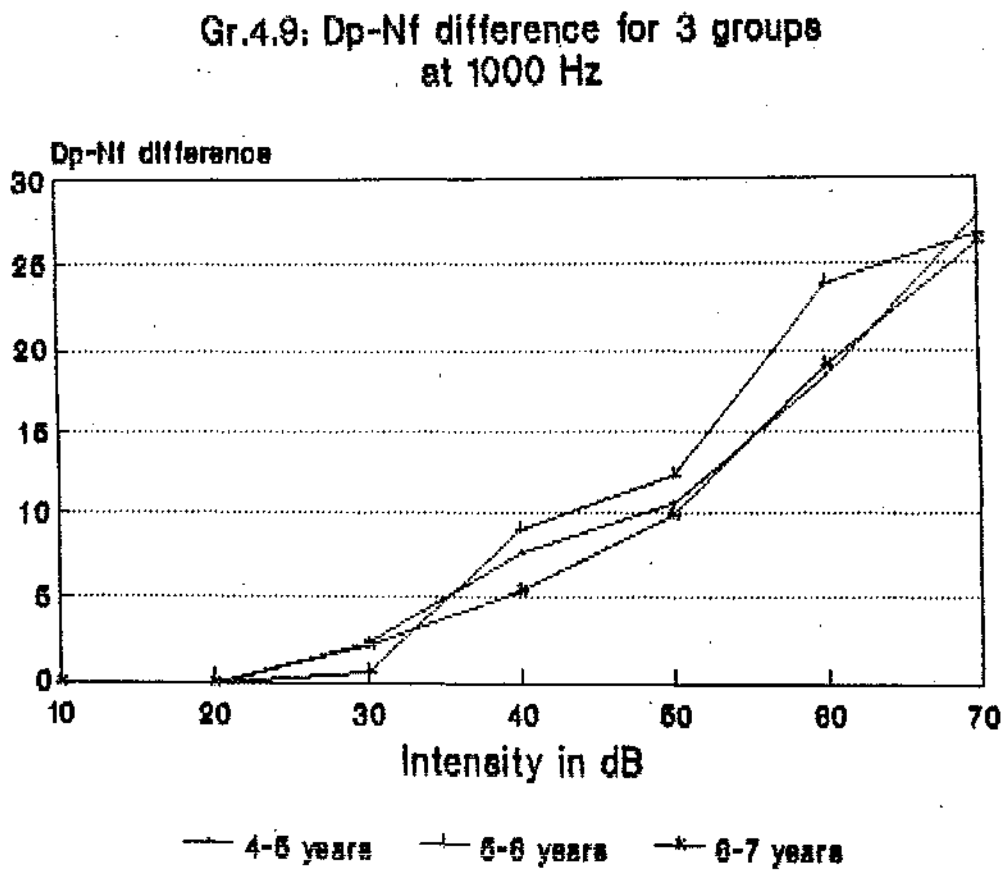


Gr.4.7: Dp-Nf dfferences for 3 groups
at 4000 Hz



Gr.4.8:Dp-Nf difference for 3 groups
at 2000 Hz





Graphs (4.6 to 4.9) shows distortion product and noise floor level differences. Slope of this difference is similar to the slope of DPOAE amplitude obtained. It is noticed that as intensity increased, the difference also increased. It is also noticed that, slope obtained for low level primaries was steep, which gradually became shallow as the level of primaries increased from 50 dB HL.

Graph (4.9) shows the differences at 1000 Hz region. It is noticed the slope for low level primaries of Group I (4-5 years) falls below the slope of Group Hand Group III. This is attributed to increase in the noise floor level. However, at higher intensities of primaries, slopes obtained for Groupl is similar to Group II and Group III.

Detection threshold

Mean, SD and range of detection threshold for 3 groups across the frequency is represented.

Table-4.5: Detection threshold (in dB SPL) in children of age range 4-5 years

Frequency (Hz)	Mean (dB)		SD (dB)		Range	
	Female	Male	Female	Male	Female	Male
1000	50	40	7.87	6.22	30-60	20-50
2000	30	20	6.97	4.99	10-50	10-30
4000	20	20	4.12	5.63	0-30	0-30
8000	20	20	4.9	4.62	10-30	10-30

Table-4.6: Detection threshold (in dB SPL) in children of age range 5-6 years

Frequency (Hz)	Mean (dB)		SD (dB)		Range	
	Female	Male	Female	Male	Female	Male
1000	40	40	6.92	9.34	30-60	20-50
2000	30	30	5.33	4.26	20-40	20-40
4000	30	20	6.44	4.02	10-40	0-30
8000	20	20	4.22	5.27	0-30	0-30

Table-4.7: Detection threshold (in dB SPL) in children of age range 6-7 years

Frequency (Hz)	Mean (dB) Female	Mean (dB) Male	SD (dB) Female	SD (dB) Male	Range Female	Range Male
1000	40	40	8.32	7.33	30-60	30-60
2000	40	30	10.9	7.96	30-60	20-50
4000	30	20	7.37	6.4	10-40	10-30
8000	30	30	4.32	6.66	10-40	0-40

Table-4.5 shows, mean, SD and range, of detection threshold for children in the age range of 4-5 years. It was observed that detection threshold decreased with increase in frequency. Detection threshold became poorer in the frequency region of 1000 Hz. This can be attributed to increase in the noise floor levels. The noise floor decreased from -12.67 to -26.76 at 1000 Hz. A study done by Whitehead et al. (1993) showed that typical noise level in adults ranged from -5 dB to -25 dB SPL above 1 KHz and increased considerably at and below 1 KHz for infants and young children.

Results obtained for children in the age range of 5-6 years (Table-4.6) and 6-7 years (Table-4.7) showed that the detection threshold were slightly poorer in older children, t-test was applied to check whether the differences were statistically significant.

Table-4.8: Comparision of DPOAE detection threshold for 2 groups, 4-5 years and 5-6 years across frequencies

Frequency (Hz)	t-values	
	Male	Female
1000	2.63*	1.71
2000	1.8	0.16
4000	1.6	1.30
8000	2.04	0.25

The differences found were statistically insignificant except for females in 1000 Hz region. Thus, there is no significant variation in the DPOAE detection threshold, moving from 4 years to 6 years.

Table-4.9: Comparision of DPOAE detection threshold for 2 groups, 5-6 years and 6-7 years across frequencies

Frequency (Hz)	t-values	
	Male	Female
1000	0.73	1.73
2000	0.45	2.95*
4000	1.6	0.76
8000	1.44	1.41

The above table shows that the differences found were statistically insignificant except for males in frequency 2000 Hz.

Table-4.10: Comparision of DPOAE detection threshold across frequencies for age groups 4-5 years and 6-7 years

Frequency (Hz)	t-values	
	Male	Female
1000	2.9*	2.04**
2000	2.8*	3.46*
4000	1.25	1.56
8000	1.29	1.68

* significant at both levels

** significant at 0.05 level

It is noted that statistically significant changes occur in the frequency region 1000 Hz and 2000 Hz for males and females. For frequency region of 8000 Hz and 4000 Hz the changes are not statistically significant.

It is observed that mean detection threshold was better in 4-5 years group in the higher frequency region like 1000 Hz and 4000 Hz than the older groups. But there was no statistical significant differences between the Group I (4-5 years) to Group II (5-6 years) and Group III (6-7 years). A similar result is also observed in the age group 20-30 years done by Martin et al. (1990). It was noted that detection threshold increased with age especially for test frequencies at 4000 Hz and 8000 Hz.

In the present study detection threshold increased from Group I to Group III agreeing with previous studies which pointsout the increase in detection threshold with the increase in age (Lonsbury-Martin, 1990; Lafreniere, et al. 1991; Hecox, 1992).

t-test was applied to see whether there is any significant gender differences.

Table-4.11: Comparision of DPOAE detection threshold in males and females.

Frequency (Hz)	t-values
1000	1.09
2000	1.43
4000	0.94
8000	1.03

The Table 4.11 shows there is no statistically significant difference between males and females.

SUMMARY AND CONCLUSION

DPOAE emissions are seen due to interaction of 2 tones, separated in frequency by a given number, presented simultaneously (Kemp, 1981). DPOAE are said to be affected by age-related changes. It is essential to establish if DPOAEs can detect age related alterations to the OHC, as such data is important with respect to determining the practical usefulness of DPOAE measures.

This study was taken up in the aim of -

(1) Obtaining 1-0 function of DPOAE in children that is to study the detection threshold, maximum amplitude and slope.
(2) To document the age related changes.
(3) To document gender differences, if any.

In this present study, 30 subjects (15 males and 15 females) whose age ranged from 4 years to 7 years with normal hearing were tested. DPOAE were measured using the Bio-logic Scout Plus System (software version 1.22) in a sound treated room.

The obtained data were subjected to statistical analysis (mean, SD and t-test of significance).

The analysis revealed the following :

(1) DPOAB emission were present in all the subjects,

(2) Detection threshold increased as age increased. There was significant difference in detection threshold obtained between the age groups 4-5 years and 6-7 years.

(3) The average maximum amplitude steadily decreased with age. The difference across frequencies were not statistically significant.

(4) 1-0 slope showed that DPOAE amplitude increased with increased in stimulus level.

(5) DPOAE amplitude increased with increased in frequency from 1 KHz to 8 KHz with a peak at 4 KHz.

(6) No significant gender difference were obtained.

The measured values can be used as a normative data and thus can be used as clinical tool for screening and diagnostic purposes.

Limitations of the study

(1). Age group undertaken is limited

(2) More number of subjects is needed to be studied

(3) 1-0 function in lower age group is needed to be determined.

(4) 1-0 function in hearing loss should be determined, to know how it varies with different etiologies.

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