RELATIONSHIP BETWEEN OAES AND BEHAVIOURAL DISCRIMINATION ABILITY OF NORMAL HEARING INDIVIDUALS

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Abstract

Frequency selectivity and Otoacoustic emissions (OAEs) have been shown to exhibit some relationship, which may explain the psychoacoustics of the ear on peripheral testing. The current study attempts to find the relationship between the amplitudes of OAE and frequency discrimination abilities across frequencies within an individual. The amplitudes of Transient Evoked Otoacoustic Emissions (TEOAE) (signal to noise ratio - SNR), TEOAE (absolute amplitudes) and Distortion Product Otoacoustic Emissions (DPOAE) were measured at 1, 1.5, 2, 3 and 4 kHz respectively in ten ears with normal hearing. Difference Limen for Frequency (DLF) and Frequency Modulated Difference Limen (FMDL) were measured at ten and forty dBSL at the frequencies at which maximum and minimum TEOAE / DPOAE amplitudes were obtained. The difference limens were compared across the frequencies at which maximum and minimum TEOAE / DPOAE amplitudes were obtained. There was no significant difference between frequency discrimination abilities at frequencies with maximum and minimum OAE amplitudes. The results showed that within an individual, the OAE amplitudes might not give information regarding the frequency discrimination abilities. The OAE amplitude not only depends on the status of the outer hair cells. The amplitude also varies with several other factors like the resonance properties of the middle and external ears. Hence, no one to one correlation was obtained. OAEs may not give reliable measures to draw information about the behavioral discrimination ability of individuals.

Key Words: DLF, FMDL, TEOAE, DPOAE

Otoacoustic emissions (OAEs) that arise from the most vulnerable cellular mechanism in the cochlea, which is of fundamental importance to hearing: the outer hair cell (OHC) population; are used to evaluate the OHC functioning. These may also reflect the active biological mechanisms in the cochlea (Brownell, 1990; Norton & Stover, 1994; Zwicker, 1986). The cochlea is the centre for any entering sound to be subjected for frequency analysis. Frequency analysis refers to the ability of the auditory system to separate or resolve (to a certain extent) the components in a complex sound. It does depend to a large extent on the filtering that takes place in the cochlea. The OAEs may provide useful information in this area of frequency selectivity and sensitivity.

With reference to the frequency selectivity and sensitivity and their relationship with frequency discrimination abilities, several studies have been done since the 1990s. A relationship has been shown between physiologic measures [(Spontaneous Otoacoustic Emissions - SOAEs) and [Transient Evoked Otoacoustic Emissions)] and psychoacoustic measures (psychoacoustic tuning curves) in normal hearing subjects by Micheyl and Collet in 1994. The results revealed significant differences at 2 kHz in the quality of Psychoacoustic Tuning Curves (PTC) between subjects with and without SOAEs. This study indicates that the frequency analysis is better in the ears with better OHC functioning. However, in the same study larger Transient Evoked Otoacoustic Emissions (TEOAE) was associated with poorer frequency selectivity, whereas smaller TEOAEs were associated with better frequency selectivity at 2 kHz. The differences in the results may be attributed to the type of emission measured, stimulus levels and method differences. Sridhar K. (2000) found that the

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ears with larger Distortion Product Otoacoustic emissions (DPOAE) had better Frequency Modulated Difference Limens (FMDL) compared to the ears with smaller DPOAEs at 2 kHz. These results supported the relationship between electro physiologic and psychoacoustic measures in normal hearing subjects.

Therefore, it is not clear if the different types of OAEs show the same characteristic in representing the functioning of OHCs and also if OAEs are reliable tools to assess frequency selectivity of these cells. The current study uses three kinds of OAE measures: TEOAE (signal to noise ratio - SNR), TEOAE (absolute amplitude), and DPOAE, and compares the physiological measures with two kinds of frequency discrimination measures. The minimum difference in frequency to differentiate one from the other are calculated using Difference Limen for Frequency (DLF) and Frequency Modulated Difference Limens (FMDL) procedures at two sensation levels to rule out the masking effect of higher amplitude signals on frequency discrimination.

The major difference though in the earlier studies and this one is that the comparisons are made across frequencies with in subjects. The study hence, seeks to find out if frequency selectivity can be measured as a function of OAE amplitudes with in an individual across frequencies from 1 kHz to 4 kHz. The aims of the study are as follows:

1. To find the relationship between frequency discrimination using DLF/ FMDL and TEOAE on signal to noise ratio (SNR) amplitudes/ absolute amplitudes at those frequencies with maximum and minimum amplitudes respectively.
2. To find the relationship between frequency discrimination using DLF/ FMDL and DPOAE amplitudes at those frequencies with maximum and minimum amplitudes respectively.
3. To find the effect of sensation levels on frequency discrimination using DLF/ FMDL at those frequencies with maximum and minimum OAE amplitudes.

Method

Ten ears (eight males & two females) were taken for the study. The age range was from 18 to 24 years. They all had their pure tone thresholds from 1 kHz to 4 kHz with in 15 dB HL. Thresholds were estimated using OB-922 version 2 clinical audiometer with TDH-39 headphones. They all had 'A' type tympanogram. The Immittance testing was done using GSI Tympstar. None of them had any history of a neural problem.

Transient Evoked Otoacoustic Emissions (TEOAE) of subjects was obtained at 1 kHz, 1.5 kHz, 2 kHz, 3 kHz & 4 kHz in two ways respectively. ILO 292 was used to measure the Transient Evoked Otoacoustic Emissions (TEOAE). The SNR values and absolute amplitude values were taken at each of the frequencies. The two frequencies in both the conditions with maximum and minimum intensities were considered respectively. Distortion Product Otoacoustic Emissions (DPOAE) was administered in the same ear as the TEOAE using the same instrument, and the amplitudes were taken at each of the 5 frequencies: 1 kHz, 1.5 kHz, 2 kHz, 3 kHz & 4 kHz respectively. The frequencies with maximum and minimum amplitudes were noted. The Difference Limen for Frequency (DLF) and Frequency Modulation Difference Limens (FMDL) were found in each of the ears at all frequencies at which any of the three tests revealed maximum and minimum OAE amplitudes. To obtain Just Noticeable Difference (JND) for frequencies, the OB-922 version 2 clinical audiometer was used in the advanced mode.

To obtain difference limen for frequency, two tones were presented for durations of 500 ms each with an inter pair gap of 200 ms, the tones were such that, one of them was a frequency considered after the OAE tests. It was kept constant and the other tone was varied in 1 Hz steps. Ex.: 1000 Hz and 1001 Hz, 1000 Hz and 1002 Hz etc. The subjects were instructed to say if the tones presented were same or different. Subjects were given tones of the same frequency and two tones with a large frequency difference to familiarize them to the task. Then the bracketing method was used to establish the DLF at each frequency. The minimum difference in the tones at which the subjects indicated a difference for 75% of the times was considered as Just Noticeable Difference (JND). The other parameters of the signals were kept constant. This test was done at both 40 and 10 dBSL.

Frequency Modulation Difference Limens was obtained using the same audiometer. The subjects were first trained to listen to two tones with widely differing modulations such as 0% and 7.5% frequency modulated (FM) tones to familiarize them to the task. The actual test began with the presentation of a tone with high modulation. The subjects were instructed to say whether the tone presented was modulated or continuous. For every three consecutive positive responses to the modulated signal, the percentage of modulation was reduced. This was continued till one negative response was obtained i.e. when the subject said that there was no more modulation in the tone. That minimum modulation of frequency at which the subjects indicated the last three positive responses was taken as the FMDL. The test was done at both 40 and 10 dBSLs at the same frequencies as tested for OAEs. The modulations given were in these steps: 7.5%, 5%, 2.5%, 1.0%, 0.5%, 0.2% and 0%..

The analysis of the numerical data was done using SPSS (version 10) software. The values of DLF were obtained in hertz (Hz) called delta 'f' (df). FMDL values were obtained in terms of percentage. Hence, to make a comparison across the two methods of obtaining difference limens the delta 'f' (df) values were converted as relative percentages according to the formula (df / f * 100) where 'f' refers to the frequency tested for DLF. These relative values were tabulated. Wilcoxon Signed Ranks test was used to compare the DLF and FMDL at 40 and 10 dBSLs at frequencies with maximum and minimum amplitudes as indicated by the OAEs.

Results

The study compared 2 variables in 2 conditions each with respect to 3 testing procedures. The mean values and standard deviations of difference limens in percentage in each of the parameters were computed. They include the values of DLF and FMDL at 40 and 10 dBSLs at those frequencies with maximum and minimum amplitudes as obtained on the TEOAE (SNR), TEOAE (absolute amplitude) and DPOAE. These are shown in Tables 1, 2 and 3 respectively.

The Wilcoxon Signed Ranks Test was done to find the differences in difference limens (DLF & FMDL) with respect to the frequencies with maximum and minimum amplitudes as obtained by the three OAE procedures at 40 and 10 decibels above the pure tone thresholds at each frequency. The results showed no significant differences across the difference limens at frequencies with maximum and minimum amplitudes in all the tests. The frequencies with maximum and minimumamplitudes in TEOAE or DPOAE did not have better and poorer frequency discrimination scores respectively in either DLF or FMDL methods at the two sensation levels of 40 and 10 dBSL.

Test for DL	Max/ Min	Mean (df/f*100)	SD
DLF/ 40	Max	0.3640	0.395592
DLF/ 40	Min	0.4520	0.454045
DLF/10	Max	0.6240	0.573860
DLF/10	Min	0.5505	0.503408
FMDL/ 40	Max	1.3500	0.818196
FMDL/40	Min	1.2500	0.677003
FMDL/ 10	Max	1.4700	0.923821
FMDL/10	Min	1.7000	0.856349

Table 1: *Mean and SD values of the difference limens in percentage at 40 and 10 dBSLs at frequencies where amplitudes of TEOAE (SNR) were maximum or minimum.*

Test for DL	Max/ Min	Mean (df/f*100)	SD
DLF/ 40	Max	0.3645	0.463318
DLF/40	Min	0.5960	0.678597
DLF/ 10	Max	0.4325	0.526526
DLF/10	Min	0.6245	0.670806
FMDL/ 40	Max	1.4000	0.774597
FMDL/40	Min	1.2000	0.714920
FMDL/ 10	Max	1.5500	0.831665
FMDL/10	Min	1.7000	0.856349

Table 2: *Mean and SD values of the difference limens in percentage at 40 and 10 dBSLs at frequencies where amplitudes of TEOAE (absolute amplitude) were maximum or minimum.*

Test for DL	Max/ Min	Mean (df/f*100)	SD
DLF/ 40	Max	0.5160	0.376186
DLF/40	Min	0.4620	0.461009
DLF/ 10	Max	0.7130	0.548696
DLF/10	Min	0.5080	0.502080
FMDL/ 40	Max	1.3500	0.818196
FMDL/40	Min	1.2500	0.677003
FMDL/ 10	Max	1.6200	0.960093
FMDL/10	Min	1.4000	0.774597

Table 3: *Mean and SD values of the difference limens in percentage at 40 and 10 dBSLs at frequencies where amplitudes of DPOAE were maximum or minimum.*

Discussion

The results of the current study show no relationship between the amplitudes in OAEs across frequencies and the just noticeable difference for frequencies with in an individual. Earlier studies have dealt with the relationship between amplitude of OAE and DLF/ FMDL at particular frequencies in a group of subjects. They have shown that a positive relationship does exist when compared with in a frequency. Sridhar (2000) found that the ears with larger DPOAEs had better frequency discrimination at 2 kHz. However, it is now found that the relationship does not remain the same across frequencies. The frequencies, at which the OAE amplitudes are better, need not have the smallest DLF or FMDL. The findings in the paper can be attributed to the following reasons.

Otoacoustic emissions may not be good indicators of the actual functioning of the outer hair cells across the wide range of frequencies. But, OAEs have been relatively successfully used in threshold estimation with the assumption that they provide frequency specific information.

Secondly, the spectrum of OAE not only depends on the integrity of the outer hair cell functioning, but also depends on the resonance properties of the middle ear and the external ear. It is more likely that larger OAE amplitudes can be seen either at the middle ear resonance frequency or at the external ear resonance frequency, thus reducing the sensitivity of assessing the actual integrity of the outer hair cell functioning.

However, the amplitudes of OAE are also extremely variable with in an individual over time. Wit & Dijk (1979) found that the magnitudes of the responses measured in OAE were also influenced by the stimulus frequency and that the higher frequency stimuli generated smaller emissions than the lower frequencies. This may also be accounted for the differences in the actual functioning and the measured values. On the other hand Norton & Neely in the year 1987 said that the spectra of TEOAEs resemble those of the evoking stimuli. But, the amplitude of the evoking signal may not be the same across frequencies. Therefore, studies in the past have shown both sides of the same tests.

We may also speculate that it is not a possibility to draw comparisons of DLF / FMDL across frequencies. Researchers in the past have found values of DLF at various frequencies, though the comparisons were not made across frequencies. To make the comparisons meaningful, the values in the current study were converted into percentages. Yet, differences couldn't be seen in the study. What is even more interesting is that even a negative trend is not being seen.

Based on the results obtained, we can confirm that the outer hair cells may only have the function of separating the speech input grossly, and may not have much of a role in further analysis of the signal. Even if it does participate in more complex processes the OAEs may fail to detect it. The amplitude measured in the OAEs may not be the sound transduced into the auditory pathway.

On the basis of the results of the current study, we may say that the level of presentation of the stimulus has no effect on the relationship between the frequency discrimination abilities and OAE amplitudes. Therefore, we may suppose that the OAEs are not reliable measures of OHC functioning as they are influenced by other physiological factors. Thus it fails to correlate the physiology of the OHCs with the perceptual ability of the individual. Hence, the scope of OAEs in indicating the psychoacoustic characteristics may well be limited.

Conclusions

Previous studies have shown different patterns of relationship between OAE amplitudes and frequency discrimination, the frequencies being considered across individuals. The results of the present study, which compared the relationship across frequencies with in the same individual, do not reveal any such pattern. A relationship followed well across ears at a frequency doesn't hold well across frequencies within an ear. Hence, interpretation of the amplitude differences across frequencies in the OAEs of an individual should be made with caution.

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