"CENTRAL MASKING AND ITS EFFECT ON THRESHOLD IN INDIANS"

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"Dedicated to my beloved parents "

CERTIFICATE

This is to certify that the dissertation entitled " CENTRAL MASKING AND ITS EFFECT ON THRESHOLD IN INDIANS " is the bona-fide work in part fulfilment for M.sc in Speech and Hearing of the student with Register No.3

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This is to certify that this dissertation has been prepared under my supervision and guidance.

Date:

Guide

DECLARATION

This dissertation is the result of my own study undertaken under the guidance of Mr.S.P.C. Pandalay, 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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CHAPTER I

INTRODUCTION

The threshold of audibility increases when a complete acoustic insulation between the two ears is achieved. This effect, results from neural interaction, is called central masking. It is simply the reflections of neural activity at low levels of the auditory system. Central masking phenomenon was first discovered by wegel and Lane (1924) and it was defined as a conflict of sensations in the Brain.

Ward (1967) concluded that contralateral remote masking which arises at one or more centers receiving afferent innervation from both the ears. However, Liden, Nilsson and Anderson (1959) reported that central masking is probably mediated by the efferent pathways. Central masking occurs when the test tone is presented to one ear and the masking sound to the other ear at a level in-sufficient to affect the test ear directly, small change in threshold of the test ear is observed. This threshold shift is a simple measure of the neural activity produced by the extrinsic noise in the contralateral ear. Not all the noise induced neural activity can be measured by means of central masking; only that portion which interacts with nervous system excited by the test signal produces a contralateral threshold shift. The narrow band signal of low intensity excites only a small group of neurons and this group may be expected to intract from the contralateral ear. Thus by changing the centre frequency of the signal, different excitation patterns can be observed.

The threshold of audibility is determined by a constant signal-to noise ratio in the neural domian. The arising threshold shift is very small and does not exceed 10 dB. It is maximum when the masking noise is presented in bursts and the threshold is determined at the onset of the burst. The threshold shift rapidly decreased with time delay and also when the frequency difference between the test signal and masking sound increases.

Zwicker, Flottorp and Stevens (1957) reported that the major portion of central masking produced by a 1 KHz bone occupies a frequency bandwidth of approximately one critical band. Central masking increases with increase in intensity and when the masker is set at several sensation levels changes in frequency distribution pattern takes place with increase in sound intensity. Other words distribution becomes broader as the sound intensity increases. The narrow band and wide band noise does not make any difference as long as the centre frequency of the narrow band is not identical to the nominal frequency under test.

Fletcher (1940) reported that only a small part, the critical band, of a wide band masker contributes to the masking of a tone.

Generally, the masking of tones at low frequency increases less rapidly than the masker level and at higher frequency, masking increases more rapidly.

At higher noise levels, masking decreases more, rapidly with increasing loudness level than at low noise levels or than with a wide band masker Hellman, 1970; Zwicker, 1963 . Furthermore, against narrow band noise, masking disappears when the noise level is about 20 dB lower than the level of the tone.

Masking not only depends upon the spectra and intensity of the masking signals but depends also on the duration of the signal. The signal can either be continuous or intermittent generally, if the spectrum and intensity of the continous noise are adequate, the masking effect will be permanent as long as the noise is present (Egan and Weiner, 1964; Fletcher et al 1950). The effect of the intermittent noise on masking, however, will be temporary depending upon the length of time the noise is present (Pollack, 1955),

Several studies have shown very small effect for a continuous masker and a puled test stimulus and somewhat larger effect when both are pulsed. Also a sharp frequency selectivity has been revealed.

Zwislocki in his systematic studies on central masking which began in 1963 gives a psychophyslological theory of central masking with the help of an elementary mathematical theory based on three paostulates. They are:-

1. Signal detectability in determined by signal-to-noise ratio in the neural domine.
2. Neural inputs from the two ears are arithematically added in a binaural integrating stage.
3. The driven neural firing rate is directly proportional to sound intensity at low intensity levels*

Neural firing decay with increasing time from the onset of stimulation. The decay has been demonstrated extensively at the level of the 8th nerve (Deskyshire and Davis 1935).

Kiang (1965) supported the above statement but indicated two phases, (a) fast with a time constant on the order of 50 m.sec and the other (b) slow with a time constant in excess 1 min. The fast decay accounts for about 50% to 70% of threshold shift at medium and high stimulus level and gradually vanishes when the level is decreased to-wards the threshold. The slow decay adds about 15% to as much as 80% so that a new component is added to the decay of single unit activity when stems from the neural refractory period. The fast decay of the unit activity is presented; at the level of the cochlear nuylus and appears to be reflected in the slow waves of the superior olivary complex. Psychophysically the neural decay is fixed in central masking.

Zwislocki (1968) has shown that the amount of decay appears to be directly related to the threshold shift at the masker onset. The greater the shift more pronounced is the decay.

Katsuki (1961) observed the decay of neural group activity throughout the auditory nervous system and it was more pronounced at higher nuclei. Zwislocki (1972) concluded that characteristics of many neurons of the cochlear muscles are not reflected in central masking characteristics while those of other neurons of the cochlear muscles and of superior olive as well as of all neurons of the eight nerve are.

The threshold shift produced by central masking is very small and grows much less with the masker intensity than does the threshold shift produced by monaural masking.

Zwislocki (1953) suggested that the threshold shift as a result of central masking does not exceed about 5dB, but Liden et al (1959) observed shift upto 15dB.

Studebaker (1962), Dirks and Dirks and Malmquist (1964) reported that central masking effect increases with increases in intensity of the masking noise and may be as great as 10 to 12dB.

Zwislock (1971) feels, because of the smallness of the threshold shift it produces, that it may not become a routine clinical tool but it can very well be useful as an indirect tool in the investigation of the lower parts of the neural . auditory system.

Need for the study:

Wegel and Lane (1924) provided the first description of the phenomenon and called it "central masking."

Central masking is now a widely recognized phenomenona demonstrated by a shift of auditory threshold in one ear upon the presentation of a contralateral masker. Every audiologist thus, uses a correction factor in clinical audiometry to account for the effect.

Palva (1954) found that the threshold changes generally less than lOdB due to the effect of central masking. But Liden (1959) state that the effect is 5 to 15 dB and it remains relatively constant as the masker level increases.

Dirks and Malmquist (1964) while stuying the effects of central masking both on air conduction and bone conduction thresholds found that the threshold shift for frontal bone measurement was always greater than comparable air conduction or Bone-conduction thresholds from the mastoid process.

Zwislocki et al (1968) concluded that threshold shift resulting from central masking is transient and at the onset of the masker, it may amount to 15 dB and later on reduces to about 4 dB.

Zwislocki et al (1969) in another study pointedout that when both the masker and maskee are pulsed simultanously the masking effect amounts to about 10 dB and when the masker is continuous and maskee is pulsed the effect decreases to a few decible.

Zwislocki (1971) says that the threshold shift arising from central masking is very small and rarely exceeds 10 dB.

Snyder (1973) recommends a corrective factor of 5 to 10 dB to account for the effect in clinical audiometric evaluation.

The present study was undertaken because of the contravercies and confusions in determining the exact amount of threshold shift due to central masking to be used as a correction factor in routine clinical audiomotry. when differences exists even among the population of white the disparity that would probably exists between the white and the Indians can/imagined especially whan several studies conducted at this Institute reveals the difference.

Basavaraj (1973) reported a considerable difference in the Acoustic Impedance for Indians when compared to the white.

Mythili (1975) reports slightly greater Acoustic reflex thresholds for Indian from that of White. Ragunath (1976) recommends a different value to be substituted in the formula to calculate pure tone thresholds from reflex thresholds for Indians.

So this ia an attempt to investigate the effect of central masking on Indians and whether the results are comparable with that of whites. Attempt ia also directed to find out whether the effect is constant at all the audiometric frequencies and if not what would be the correction factor to be used in our clinical audiometry.

Purpose of the study:

The present study was aimed at determining the amount of threshold shift owing to the phenomenon of central masking on Indians.

This study was therefore designed to answer the following questions.

1. Will there be any difference in the amount of threshold shift for puretones when White or narrow band noise is used as masker?
2. Will different levels of noise have differential effects upon the threshold?
3. Will the threshold shift due to central masking is same or not for all the audiometric frequencies?
4. Will there be a difference in the amount of threshold shif when the masker used is continuous or pulsed noise?
5. Will the threshold shifts due to central masking thus, obtained be comparable with the results of other studies conducted on western population?

Brief plan of the study:

A group of 60 normal hearing adults, comprising both males and females, within the age range of 18-24 years were selected for the study.

These subjects were divided into two experimental groups each consisting of 30 subjects. In experiment I, the test signal was intermittent and the masker was continous whereas in experiment II both masker and maskee were pulsed. Further each experiment was conducted through three stages.

First, the threshold of sensitivity for pure bones was determined for frequencies 250 Hz to 4 KHz. Second, the threshold of sensitivity for narrow band noise whose centre frequencies varied from 250 Hz to 4 KHz and also for white noise was determined. Last, the threshold shift was determined by presenting thetest bone in one ear and continuous noise in the contralateral ear. The threshold shift was determined for 20 dB SL, 30 dB SL and 40 dB SL. of white band and narrow band noise.

In the second experiment the procedure was same except that both the stimuli were pulsed.

Factorial design was used for the conduct of the study and the results were analyzed statistically by using analysis of variance.

Implications:

1. It gives the clinician an idea about the possible threshold shift that can be produced because of the phenomenon of central masking.
2. It provides the dB value to be deducted from the masked threshold for every audiometric test frequency as a corrective factor for central masking.
3. Central masking may become an indirect tool in the investigation of the normal and pathological auditory nervous system.

Limitations:

1. The effect of central masking on Bone conduction audiometry could not be determined.
2. The possible change in central masking when an insert reciver was used could not be determined.
3. The study has not included some clinical cases for observation of the effect.
4. The central masking effect when the test frequency was kept constant varying the masker frequency could not be investigated due to the instrumental limitation.

Definitions:

1. Normal ear: The ear with no apparent abnormality revealed either by history or by E.N.T. examination and with hearing sensitivity below 20 dB HTL (ANSI 1969).

*2 Pure Tone: Pure tone is a sound produced by an instantaneous sound pressure which is a simple sinusoidal function of time.

*3. Threshold: Threshold is the least audible sound pressure level often defined as the level of a sound at which it can be heard by an individual 50% of the time.

4. Sensation level: sensation level of a sound is the intensity of the sound in dB above its absolute threshold . level (Licklider).

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*Taken from Fredrick N. Mastin, Introd to Audiology (Englewood Cliffs., N.J: Prentice -Hall 1975)

5, Narrow band noise: In a sound in which energy is concentrated with in a small frequency interval (Glorig A; 1965).

6. White Band noise: White band noise is a sound in which energy is present over a wide range of frequencies with equal energy per cycle (Glorig A, 1968, Martin F. 1975).

*7 Critical Band: Critical band is the restricted band of frequencies surrounding a puretone and where the SPL of tone and noise are equal to tone is barely perceptible.

8. Central masking: when a noise is presented to the untested ear at a level insufficient to affect the test ear directly, a small change in thresholds of the test ear may often be observed. This phenomenon is assumed to be a function of the central nervous system and has been labbled as central masking.

9. Frequency: The frequency of a puretone represents the number of complete cycles (Hz) that the sound wave has passed through in a 1 sec. time period.

CHAPTER II

REVIEW OF LITERATURE

The central masking is a psychophysical phenomenon. This phenomenon of central masking was first determined by Wegel and Lane (1924). They postulated that ipsilateral masking results from an "overlopping of stimuli in the end organ" while central masking results from a "conflict of sensation in the Brain."

This conflict had been there since long time, i.e., whether the cochlea takes part in the central masking or whether it is completely the action of the neural activity of the central auditory pathway.

Ingham (1957), and Liden and Ingham (1959) reported that the central masking is neither due to the transcranial physical stinulation of the test ear nor the activation of the bitaleral acoustic reflex but the effect is somehow mediated by the central auditory pathways with or without possible efferent fiber participation.

He further studied the peripheral and central origin of the phenomenon. Low level masker was used but did not find any peripheral contribution towards central masking by cross hearing nor through contraction of the stapedius muscle. He hypothesized the process involves the simple distraction and decreased motivation under masking condition and thus accounts for central masking.

He also observed that the spread of low frequency (200 Hz) central masking was greatly wider on frequency range than that of higher frequency masker. The characteristics broad frequency spread of masking obtained with low frequency ipsilateral masker transduction of the maskers. Thus the results suggested that the central masking may also be significantly effected by cochlear processing of the masker

After several investigations it has been proved that the effect of cochlear mechanism has been considered insignificant because -

1. Central masking is less compared to ipsilateral masking.
2. Contralateral masker yielded a narrow frequency spread of central masking compared to the broad frequency spread of masking obtained during ipsilateral masking (Zwislocki et al 1967 and 1968).

The masking not only depends upon the frequency and intensity but also on duration, delaytime and type of the stimuli. All these factors show different effects on masking. It is also related to the critical Band widths of the masker. The masked threshold of the noise remains constant until the separation between the two tones reaches a critical value, after which the masked threshold decreases abruptly. The point at which this decrease begins is taken as the measure of the critical band. The location of the critical transition points in the masking curves is apparently invarient with level, at least over a range of about 80dB (Zwicker,Flottor and Steven 1957).

Hawkins and Stevens (1950) investigated the masking effects of white noise on pure tone thresholds. Results obtained showed that at low noise levels and in midfrequencies the thresholds of tones are shifted greatly than those frequencies which are above and below this region. Furthe: the sound pressure levels which are necessary to reach the masked threshold are independent of stimulus frequency at high masking levels.

Ehmer (1959) indicated that the masking pattern elicited by a pure tone stimulus results from the activity pattern set up along the basilar membrane because the coehlear patterns have shown similar asymmetrical patterns as the tone on tone masking patterns.

Egan & Hake, (1950) Ehmer (1959), Easter and Kryter (1962) replaced the pure tone masker with a narrow band noise to avoid the wavering beats produced by the signal frequency which was close to the masker.

Bilger and Hirsh, (1956) and Spieth, (1959) have also shown that a pure tone masker is highly effective at masking freqencies higher than that frequency. And on the other hand, the masking effect at frequencies lower than the masker in minimal. where as it is not the case for narrow bands when the masking level is set at high intensity levels.

The low pitched sounds have a different masking effect from that of a high pitched sound. The low pitch tone completely mask the high pitch tone but a tone of high pitch does not mask the low pitch tone (Mayer, 1876).

Generally, the masking of tones at lower frequencies increased less rapidly than the masker level and at higher frequency, masking increases more rapidly. Steven and Guriao (1967) noticed that when a white noise was used to mask a 1000 Hz tone, masking increased just about as rapidly as the masker level.

Sherrick and Mangabina-Albernaz (1961) reported that central masking is greater for higher frequencies and concluded that it can not be produced by the aural reflex. Also greater effect was noticed when masker and test signal were pulsed than when the masker was steady and test signal was pulsed. The central masking was greater as the test signal frequency approached the masker frequency of a pure tone. 1 dB threshold increase for each 10 dB masker level was observed. There was little or no change in central masking as a function of masker level in the test-signal-pulsed/noise-singal-continuous condition.

The effect of central masking on air condition and bone conduction threshold was Investigated by Dirk and Malmquist (1964). In experiment I air conduction was taken into account and in experiment II the B.c was tested via the mastoid process and the frontal bone at various narrow band noise levels. A small increase in threshold shift were observed as the Intensity level of the noise was increased for the experimental frequencies 500 Hz, 1 KHz, and 4 KHz. The changes for A.C and B.C at mastoid process were similar. But when the results of mastoid process were similar. But when the results of mastoid were compared with the frontal bone condition, the threshold shift were greater at the frontal bone. It is suggested that this additional shift in threshold is due bo the change from binaurai stimulation in quiet to monaural stimulation during the masking condition. In order bo test this proposition, the test ear of 6 subjects were plugged and tests were made at 500 Hz. The B.C sensitivity increased and the contribution of the opposite ear to the threshold was eliminated. When noise was presented to the non-test ear, the threshold shift by A.C and B.C from either vibrator placement were found to be similar. Thus these results supported the additional threshold shift from the frontal bone condition.

Studebaker (1962) suggested that the unmasked thresholds via the frontal bone represents the equal stimulation of each ear and ware thus binaural. The threshold shift in the frontal bone, due to masking in the nontest ear was the result of central factor plus the loss induced by changing from binaural to monaural stimulation.

Dirks and Malmquist (1965) made use of five combinations of pulsed and continuous masker noises and test tones in a central masking experiment. The greatest threshold shift appeared when the signal and masker were both on continuously or when they were pulsed on and off together and when the test signal was pulsed and the masker was continuous, very little shift was observed.

The effect of masker level on the central masking was investigated. 2 dB threshol increase for each 15 dB masker level increase was noticed. There was also ao change as a function of masker level in the test-signal-pulsed/nois -signal-continuous condition. Unfortunately these results were not systematic. (Dirks and Morris 1966).

Central masking depends on the pattern of stimulus presentation. When both the masking and masked stimuli are pulsed simultaneously, the masking effect amounts to about 10 dB and when the masker is continuous and the test stimuli) pulsed the effect decreases to a few decibles. The tempers effect of central masking was investigated by presenting 10 m.sec tone bursts and masker of 250 m.sec bursts of tone or random noise which was repeated at the rate of one per second. The test bursts were presented at various time intervals from the onset of masking bursts. The results Showed that contralateral shift exceeded 10 dB at the onset of masking bursts and decreased rapidly with in about 15 m.sec and in a matter of 200 m.sec, it reduced to a few dB. When the intermittent masking and test stimuli are turned on simultaneously, the threshold shift gradually decreased by several decibles and reached an asymptotic stage within a minute (Zwislocki, Buining, and Glantz 1965)*

This shows that the contralateral threshold shift produced by central masking decays as the time delay from the masker onset increases.

In 1966 (Zwislocki and Johnson) conducted an experiment to rule out the interaction between this decay and the masker sensation level. A critical band of random noise Centered at 1 KHz was used as the masker and the threshold shift was determined by presenting 10 m.sec burst of a 100 Hz tone with the help of force choice tracking method. Data indicated that both the threshold shift at the masker onset and the rapidity of its decay increased with the masker intensity.

The influence of test tone duration on auditory masking is due to the temporal integration functions of tone burst masked by critical band noises which becomes shallower with increase of the test tone frequency. This type is seen in the bone bursts along the center as well as at the slope of the masking pattern of critical band maskers. When test tone burst is short, the horizontal masking pattern of uniform masking noise changes into a decreasing slope pattern for increasing frequency. The slope of the masking pattern of critical band maskers remains rather independent of test tone duration (Fasti, 1976).

Zwislocki and Newman (1967) studied the "time constant of the Auditory system and central masking." Here the masker freqency was 2 and 0.25 KHz. The effect of central masking was found maximum at the time of masker onset. It increased with sound intensity, but remained frequency independent when the loudness level in the entical band was kept constant. The threshold shift decays exponentially as the time delay from the masker onset is increased. It reached an asymptote at about 250 m sec. The time constant of the decay, on the order of 50 m sec. was indicated to be independent of a stimulus parameters. Thus it is considered as a system constant.

The freqency spread of masking appears to be consistent with the critical-band measures at medium masker levels but not at high or low levels. Zwicker, Flottorp, and Stevens (1957) found that the major portion of central masking produced! by a 1000 Hz tone occupies a frequency bandwidth of approximately one critical band, no matter whether it is transient or steady-state condition.

Frequency distribution of central masking has been investigated by Buining, Glantz and Zwislock (1968). They varied the masker frequency in small discrete steps from 300 to 2000 Hz and test tone frequency was maintained at 1 KHz. Both the masking and test tones was delivered through hearing aid receiver, in order to increase the Interaural sound attenuation to 75 dB and also the acorestical interaction between the ears was effectively eliminated. The results indicated the maximum threshold shift at the masking frequency of 1000 Hz or slightly lower. Below the frequency of the maximum, a shallow relative minimum which is followed by a secondary maximum or curve form a plateau. Above the frequency of the principal maximum, the masking decays monotonically. Sometimes a small hump was observed which seems to be a counterpart of the secondary maximum at low frequencies. No slow build up processes were observed, in other words the delay from the masker onset was increased, the masking distribution became gradually flattened. Also masking decaed faster where it was initially the largest.

The rate of decay does not depend upon the masker frequency, or the frequency difference between masking and test tones but on the amount of initial threshold shift. Independent of the frequency the amount of decay were similar whenever the initial amounts of masking were approximately the same.

The masker sensation level affects both the amount and the distribution of the threshold shift. The frequency bandwidth of the principal maximum was consistent with the width of the critical band at the medium levels. At hiyher levels, width and the height of maximum were increase. And at lower levels it decreased gradually until the maximum disappeared completely. The relative minimum below the test frequency was centered around the low masker levels. At the same time, a clear relative minimum appears above the test frequency. As the masker level increased, the low frequency minimum moved away from the frequency of the principal maximum. And at higher levels, the low frequency maximum and minimum indicated the tendency of degeneration and formed plateau which showed the growth with the masker level at an accelerating rate.

This bring us to the conclusion that central masking is a complex nonlinear processes. The relative maxima and minima indicates the inter-action between excitatory and inhibitory neural processes.

In these two studies mentioned above they found threshold shift as great as 11 dB when the onset of masker and test tone was simultaneous, and the shift decreased to 2-3 dB at 160 m.sec which were accounted for the pulsed Vs continuous masker and test signal. The results are found parallel between these results and those of studies of overshoot which suggest that ipsilateral overshoot may be at least a part of a central phenomena. This is also supported by the results of Strokinger and Landford (1969).

This brought them to the conclusion that central masking is a masker level dependent when the masker and test tones are presented simultaneously. This produces about a 1 dB increase for every 2 dB increase in the masker level where as the steady-state masking is independent of masker level.

Zwislocki (1972) developed a quantitative psychophysiological theory of central masking and was validated by means of psychophysiological comparisons. The theory assumes a constant signal-to-noise ratio in the physiological domain for constant signal delectabiiity, partial linear summation of dichotic inputs, and a direct proportionality between driven neural activity and sound intensity at near, threshold intensities. All assumptions are based on psychophysical and physiological evidence independent of central masking.

Following are the assumptions:-

1). Signal detectability is determined by the signal-to-noise ratio in the neural domain, i.e., the signal-to-noise ratio is constant for constant detectability. This holda for extrinsic as well as intrinsic noise.

2). Neural inputs from the two ears are linearly summated in a binaural mixing stage.

3). At low sound-intensity levels, the driven neural firing rate is directly proportional to sound intensity.

The theory is shown to predict accurately single-unit characteristics of the auditory nerve and of primary coehlear nuclei and the superior olive nuclei. Validating comparisons were made between calculated and empirical results in time, frequency and intensity domains for steady-state and transient stimuli.

A comparison was made between 8th nerve units and central masking. It has been observed that both central masking and 8th nerve units exhibit a similar and stable time characteristic. Zwislocki (1968, 1969) showed that the decay time constant has a value of approximately 50 m sec. and the amount of decay is directly related to the threshold shift at the onset of the masker. Kiang (1965) indicated the driven firing rates of an eighth nerve unit derivered from PST histograms. The firing rates have been obtained by subtracting the spontaneous activity from the total by referring them to the firing rate around 200 m sec.

The argument between the theoretical and empirical values implies a frequency independence of the time decay function, This was observed in studies done on central masking (Zwislocki and Newman, 1967) and 8th nerve firing (Kiang, 1965).

Apart from being both as a frequency independent time function, it also, implies that the firing rate of many 8th nerve units follows the same time course provided they are excited to a comparable level.

The important characteristic of 8th nerve units was determined by the relationship between the sound intensity and the neural firing rate.

The firing rate differs from unit to unit and central masking from listener to listener.

Snyder (1973) investigated central masking factor in a group of 40 normal hearing subjects. 40 dBSL contralaterai maskers of wide band noise and narrow band noise were used. 40 dBSL was selected because it is not great enough to mask the tone in the contralateral ear by transcranial stimulation (Saunders and Rintelman, 1964; Dirks and Malmaquist, 1965; Normis and Dirks, 1966; studebaker,l967; Shimizu, 1969). The test frequencies were 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz. The results indicated the increase in threshold shift with increase in frequency of the test tone and with decrease in masker band width. A correction factor of 5 to 10 dB is recommended and greater than 10 dB was observed with narrow band noise.

Bradley and Billings (1977) studied the frequency spread, temporal relation and growth of central masking using low frequency masker (200 Hz). The masker was either with a duration of 500 m.sec presented at 10 dBSL, 30 dBSL and 50 dBSL. The masker was gated tone bursts from 170 Hz to 4000 Hz and was located at the onset of the gated maskers. The results showed no significant masking at 10 dB except at 230 Hz maskee frequency, 30 dBSL masker yielded significant masking at maskee frequency from 170 Hz to 750 Hz. An upward spread of masking function that was nearly 2 octave above the masker frequency. The 50 dBSL masker yielded 4 octave above the masker frequency upto 4 KHz. Thus the low frequency spread of central masking exceeded 4 octave above the masker frequency. Therefore central masking phenomena appears to be significantly affected by cochlear transduction of the masker and maskee signals, as well as bring a function of central auditory neural interaction.

The temporal relations and growth of central masking was measured by using the gated masker (t = 5 m.sec) and the steady state masker at 230 Hz maskee frequency. The growth of gated central masking was relatively linear indicating that fixed increase in the masker intensity resulted in fixed increase in masking. A slight upturn in the slope of the growth function from 30 to 50dBSL was observed which coincides with the study done by Zwislock, Buining, and Glantz (1968). The mean interval of 51 dB with a range from 35 to 70 dB at 250 Hz for 256 unilaterally deaf sub-E-jects. It is possible that the growth of masking functions is the result of transcrarial masking effect for the 50dBSL masker. Steady state masking did not exceed 1.4 dB significant level. These results are in agreement with the test results reported by Zwislacki (1967) and Zwislacki, Buining and Glantz (1968). Zwislacki (1972) suggests that the absence of significant masking under these conditions is attributed to a reduction in 8th nerve firing under sustained stimulation from the steady state masker.

The temporal relation was studied by using both gated and steady state masker (t= 5 m sec t = 250 m sec) at 230 Hz maskee frequency. The gated masker (t + 5 m sec) yielded greater masking than steady state masker. No significant difference was noticed at 10, 30 or 50 dBsL in steady state and in gated maker at levels 10 and 30 dBSL. Zwislacki Buning and Glantz (1968) reported 6 to 8 dB central masking overshoot at 1 KHz for 60 dBSL gated masker in 3 subjects.

Though these are only few studies have been devoted on central masking ao far no attempt was made to measure the effect on our population. This would be the first attempt aimed at establishing the magnitudes of central masking on Indians at different audiometric frequencies. The study also scans the possible changes on central masking when the test tone was changed from continuous to pulsed and also where the masker was changed from continuous to pulsed at different sensation levels. The variation in central masking produced by narrow band noise and white noise was also estimated.

CHAPTER III

METHODOLOGY

The methodology of the present study comparises of the following steps:

1. To obtain pure tone thresholds of 250 Hz to 4 KHz of both continuous and pulsed tone for normal hearing subjects through behavioral audiometry.

2. To obtain thresholds for continuous and pulsed narrow bands of noise having above audiomeric frequencies as centre frequency.

3* To obtain thresholds for continuous and pulsed wide band noise.

4. To measure the threshold shift on the selected normal subjects where the test signal and noises were continuous and pulsed.

Subjects:

Sixty subjects between the age range of 18-24 years with a mean age of 17.95 years who were enrolled as students of the Mysore were selected. Out of them 35 were males and 25 females.

None of them had any previous history of ear aches or any ear complaint. All of them had normal ear structures otologically and normal hearing audiologically in both the ears with reference to 150 1964.

None of the above subjects were ever exposed to noise levels exceeding damage risk criteria as reported by Rosenbitt et al (1953) which is given at the appendix IV

There was no history of any of them having consumed any drug known to cause damage to hearing.

They were all unfamiliar to the test situation.

Equipments and Test Environment:

A caliberated (ISO 1974) dual channel diagnostic audiometer (Madsen OB 70) with TDH 39 earphones and MX 41/AR earcushions was used in this study to obtain the data. The experiments were carried out at the sound treated suit of the All India Institute of Speech and Hearing, Mysore. The noise levels in the room at various octave band are given at the Appendix-I .

The caliberation of the instruments was maintained by periodical check up by using an articifical ear (B&K type 4152) a condensor microphone (B&K type 4145), S.P.L. meter (B&K type 2203) with octave band fitter (B&K type 1613) and 250 Time/ counter (Eastern Electronic) Osci-llascope (Simeon type 485-I). was also used to study the clearity of the tones.

Test Procedure:

Measurement of Pure tone thresholds

All the subjects were first tested to establish pure tone thresholds at 250 Hz, 500 Hz, 1 KHz, 2 KHx, 3 KHz and 4 KHz, Hughson Westlake (1944) ascending procedure was used to establish pure tone thresholds. The following verbal instruction was given to every subject:-

"You are going to hear a series of musical tone first in one ear than in the other. When you hear a tone, no matter how high or low in pitch and no matter how loud or soft, please signal that you have heard it. Raise your hand when you first hear the tone and keep it as long as you hear it. Put your hand down quickly when the tone goes away. Remember to signal every time you hear a tone. Are the any questions?" (Martin 75)

First the thresholds were obtained for all the above frequencies using continuous tone and results were recorded.

The test was repeated using pulsed tones and subjects were reinstructed as above with necessary modification.

Measurement of noise thresholds:

After establishing a pure tone thresholds for continuous and pulsed tones a rest period of 5 minutes was given to every subject. Thresholds for narrow band of noise having the audiometric frequencies as centre frequency and wide band noise were established for continuous as well as when they were pulsed using the procedure adopted for the establishment of pure bone thresholds.

All the subjects were instructed the same way as mentioned above to raise the hand every time they heard the noise. Whenever the subjects had difficulty they were familiarized by presenting noise at sufficiently loud levels before the test was initiated.

Thresholds obtained for narrow bands of noise and wide band of noise both for continuous and pulsed were recorded separately.

If the two ears were exactly the same for pure tone measurement the Right ear was selected for the presentation of the test. In case where there was difference average threshold of the speech frequency was considered and the better ear was used for the masking. This was done to reduce the possibility of the masker affecting the peripherial mechanism of the test ear by cross hearing.

Establishment of Central Masking Factor:

It was established through two experiments. The subjects were randomly dividied into two experimental groups each consisting of 30 subjects.

In first experiment the test tone and the noise were continuous and in second experiment both the stimuli were pulsed.

Experiment I

Following a period of 5 min. rest after establishing noise thresholds the experiment first was started.

The subjects were seated in a chair and ask them to be relaxed. The following instructions were given:

"You will hear a continuous fairly loud noise in one year (better ear). Do not pay any attention to the noise. Please indicate by raising your finger whether you hear the tone in the opposite ear. Do not raise your finger if you are not sure of hearing the tone. Are there any questions?"

Three levels of noise 20 dBSL, 30 dBSL and 40 dBSL respectively were chosen for the centralateral stimulation. Contralateral stimulation was limited to 40 dBSL so as to rule out any possible transcrinal stimulation that would interfere with the measurement of central masking (Saunders and Rintelman, 1964; Dirks and Malmquist, 1965; Dirks and Noris 196(Studebaker, 1967; Shimizu, 1969).

The following order was used during the experimental procedure.

1. The test tone was presented to ensure the perception of it.
2. The reference tone was terminated.
3. The masker was turned on and about 2 sec later.
4. The tone was present at the unmasked thresholds previously determined for about 1 or 2 sec.

If there were no response the tone and masker were terminated. 20 sec later the procedure was repeated with the tone presentation at the next higher 5 dBSL.

The same procedure was repeated for other two levels of noise. Each time the central masking was determined by comparing the unmasked and masked thresholds. The mean central masking for 3 levels of noise, both narrow band and wide band was calculated.

The same procedure was continued to estimate the central masking at all the adudiometric frequencies with three different levels of noise in the contralateral ear.

Experiment II

After giving 5 min of rest period to the second group of subjects this experiment was carried out following the procedure described under experiment I. The only difference in experiment II was that the test tone and the noise were pulsed.

Test Reliability:

Five subjects from each experimental group were selected at random to check the reliability. A gap of 15 days was given between test and retest session.

The data thus obtained was analyzed statistically using analysis of variance.

CHAPTER IV

RESULTS AND DISCUSSION

The study was undertaken to investigate the phenomenon of central masking and the magnitude of threshold shift at different audiometric frequencies dueto the effect of central masking on Indians.

The sample selected in the present study consisted totally of 60 normal hearing subjects, 25 females and 35 males who were randomly divided into two experimental groups of 30 each.

In experimental group I continuous contralateral masker of wide band, and narrow band noise were used each at 20 dBSL, 30 dBSL and 40 dBSL to evaluate the threshold shift for continuous tones of 250 Hz, 500 Hz, 1 KHz, 2 KHz, 3 KHz and 4 KHz In experimental group II the effect of pulsed noise on pulsed test tone to produce central masking was explored.

Factorial design was used for the study and the results obtained were treated statistically using three way and four way analysis of variance.

Experiment I:

The statistical means (M) for the pure tone threshold shift at every test frequency at three sensation levels of noise of narrow band and white noise were computed. The values are given in Table I and graphically in figure I and II. The graphs clearly indicate that the amount of threshold shift increases as the noise level is increased.

Table I also shows the mean of the means of threshold shifts at three levels for each frequency. The mean of the means threshold shifts vary from 4 to 7 dB for narrow band and 3.5 to 5.5 dB for white noise.

"Statistically the variation in the threshold shifts as the frequency is varied is not found significant. Further the interaction between the noise level and the test frequencies was not statistically significant though these was an apparent increase in threshold shifts.

The amount of threshold shift produced increases as the noise level increases irrespective of the type of noise and statistically this change in the threshold shift was found highly significant at .01 level.

The interaction of threshold shift at 3 levels of noise when compared for narrow band and wide band noise was found significant at.05 level.

The data is indicated in Table 2. When the amount of threshold shift produced by narrow band noise and white noise were computed applying statistics the difference was found significant at .05 level of confidence. Further the interaction between the test frequencies and type of noise

Table 1 Mean of the threshold shifts for 3 levels for the continuous test tone

	Narrow band noise				Wide band noise			
Frequency in Hz	20dB3L	30dBSL	40dBSL	Means of the Means	20dBSL	30dBSL	40dBS	Mean of the Means
250 Hz	2.16	5.33	7.66	5.01	2.0	4.0	5.8	3.91
500 Hz	3.2	4.2	5.8	4.42	8.0	4.2	5.5	4.2
1 KHz		5.2	5.9	5.04	3.2	4.6	5.7	4.5
2 KHz	4.8	6.3	7.0	6.16	3.4	4.9	6.9	5.26
3 KHz	3.2	4.6	5.8	4.8	1.03	4.06	4.7	3.2
4 KHz	5.93	6.9	7.3	6.73	3.0	4.8	5.7	4.44

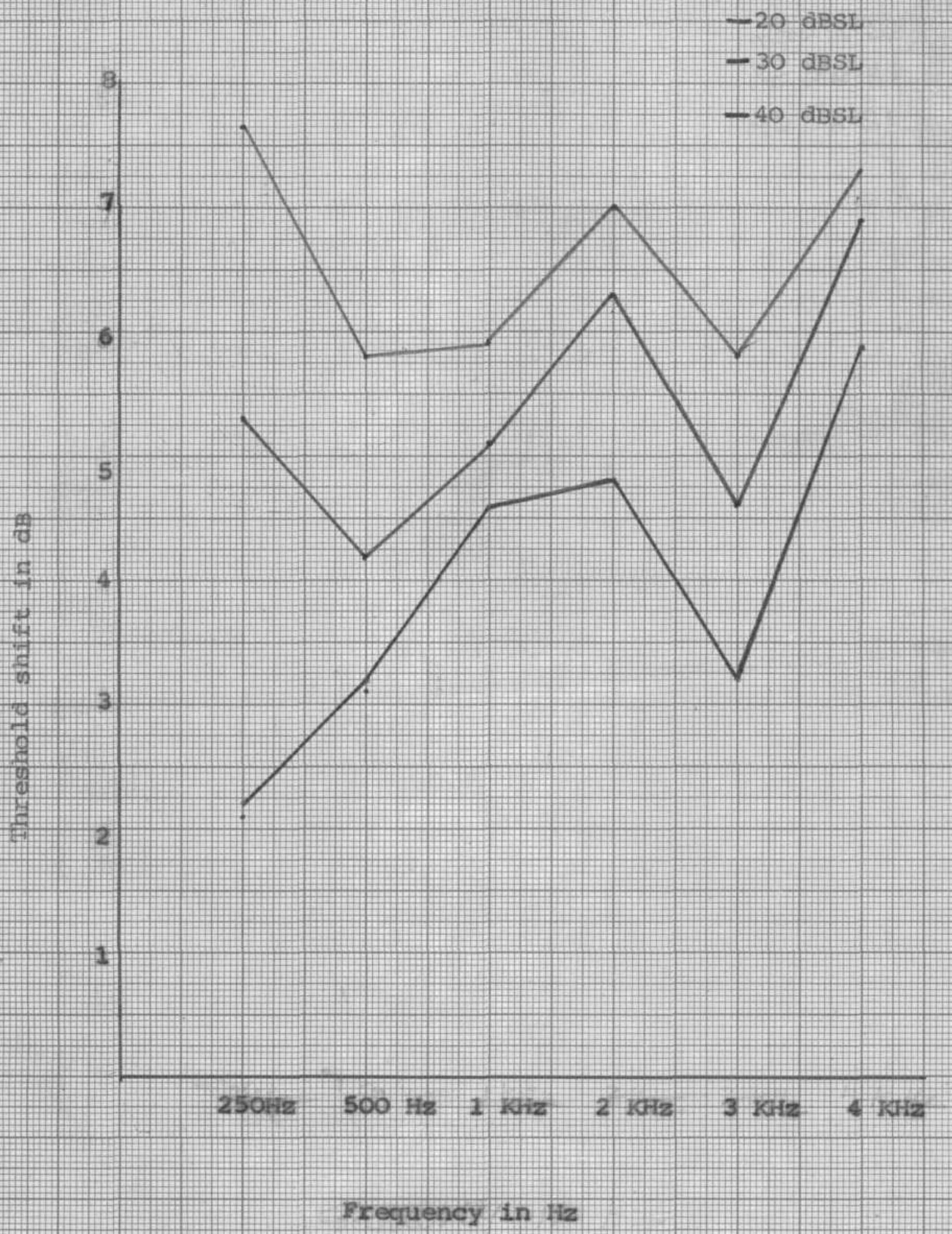
Table 2: Results of 3 way analysis of variance for the effect of pulsed narrow band and wide band masker sensation levels frequencies and their interaction effect

source of variation	SS	dv	MS	F
Due to frequencies	2900.6		2580.12	2.54
Due to type of noise	9088.4	1	9088.4	8.94*
Due to Noise levels	45829.2	2	22939.6	22.58**
Frequencies X noise levels	4601.2	10	460.12	0.45
Frequencies X type of noise	41392	5	8278.4	8.15**
Noise levels X type of noise	8413.4	2	4206.7	4.14*
Error	10156.8	10	1015.68	

* Significant at .05 level

** Significant at .05 &.01 level

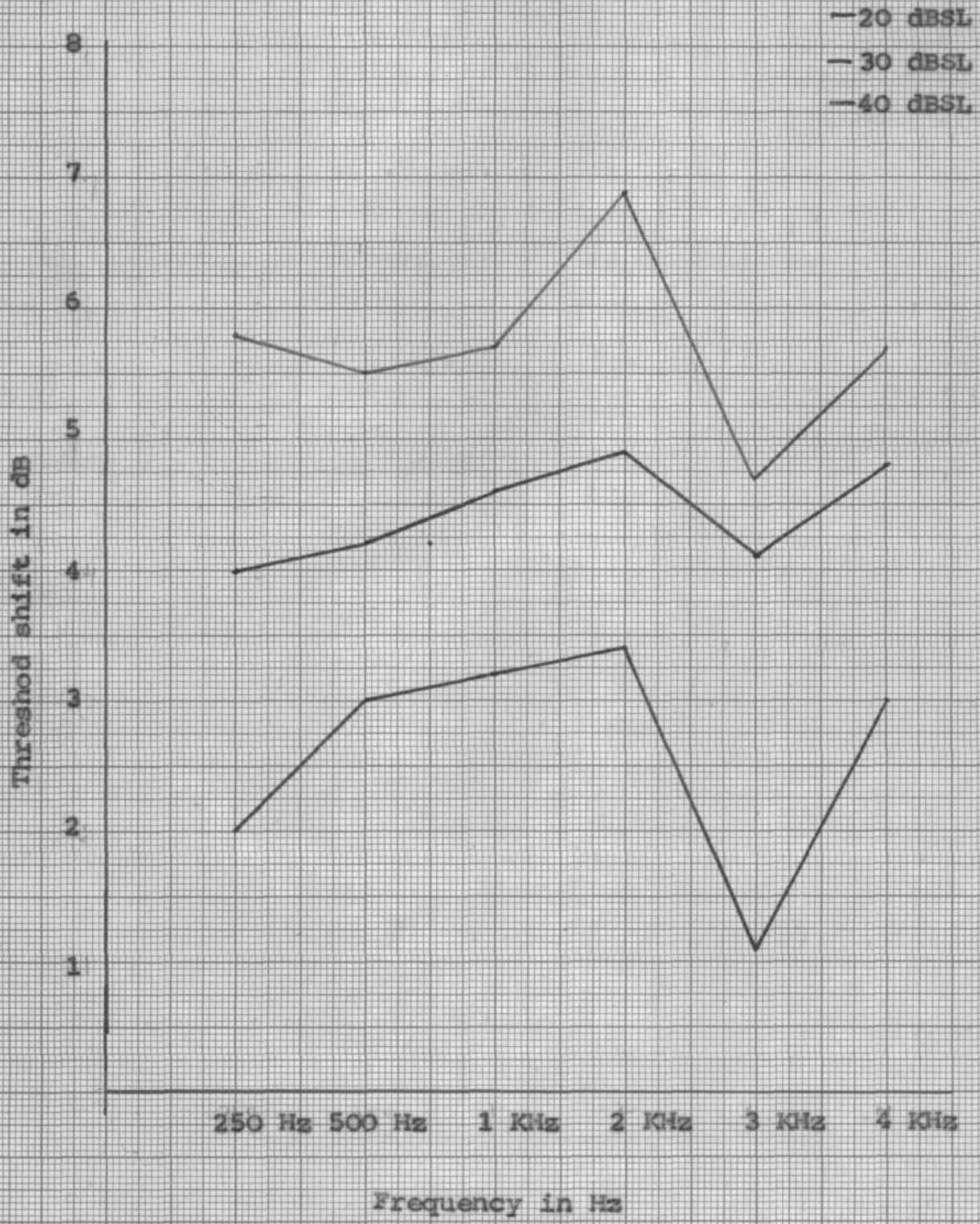
Figure I



Mean threshold shifts for the continuous tone at three levels of Narrow band noise

Figure II

Mean threshold shifts for the continuous tone at three levels of white noise



(narrow band and wide band) was statistically significant at .01 level.

Thus the effect of central masking increases as the bandwidth of the masker is narrowed.

Experiment II.

In experiment II the continuous noise and tone were replaced by pulsed noise and pulsed tone.

The central masking effect is greater than found in Experiment I. The means of threshold shifts at every test frequency at three sensation levels of noise, for wide band and narrow band were computed. Results are indicated in Table 3.

The amount of threshold shift at various test frequencies for 3 levels of noise of narrow band and wide band are represented graphically in Fig.III and IV.

The average threshold shift ranged from 7 to 12 dB for narrow band and 5 to 10 dB for wide band. Thus greater threshold shifts were found in Experiment II than those found in Experiment I (Figure V).

Statistical analysis using analysis of variance , shows that the amount of threshold shift produced for each test frequency due to central masking was found significant at .01 level of confidence.

Table 3. Mean of the threshold shifts for 3 levels for the pulsed test tone

	Narrow band noise				Wide band noise			
Frequency in Hz	20dBSL	30dBSL	40dB3L	Means of the Means	20dBSL	30dBSL	40dBSL	Mean of the Means
250 Hz	4.0	7.8	9.5	7.1	4.5	6.0	7.16	5.3
500 Hz	6.83	10.2	10.8	8.9	5.0	7.3	8.7	6.98
1 KHz	7.8	10.8	12.0	10.2	5.2	8.3	10.3	8.1
2 KHz	8.3	12.7	13.2	11.0	6.3	9.8	11.3	9.2
3 KHz	8.3	13.0	13.7	11.8	7.3	10.2	12.7	10.1
4 KHz	9.7	12.7	13.0	12	5.7	9.5	11.5	9

Figure III

Mean threshold shifts for the pulsed tone at three levels of narrow band noise

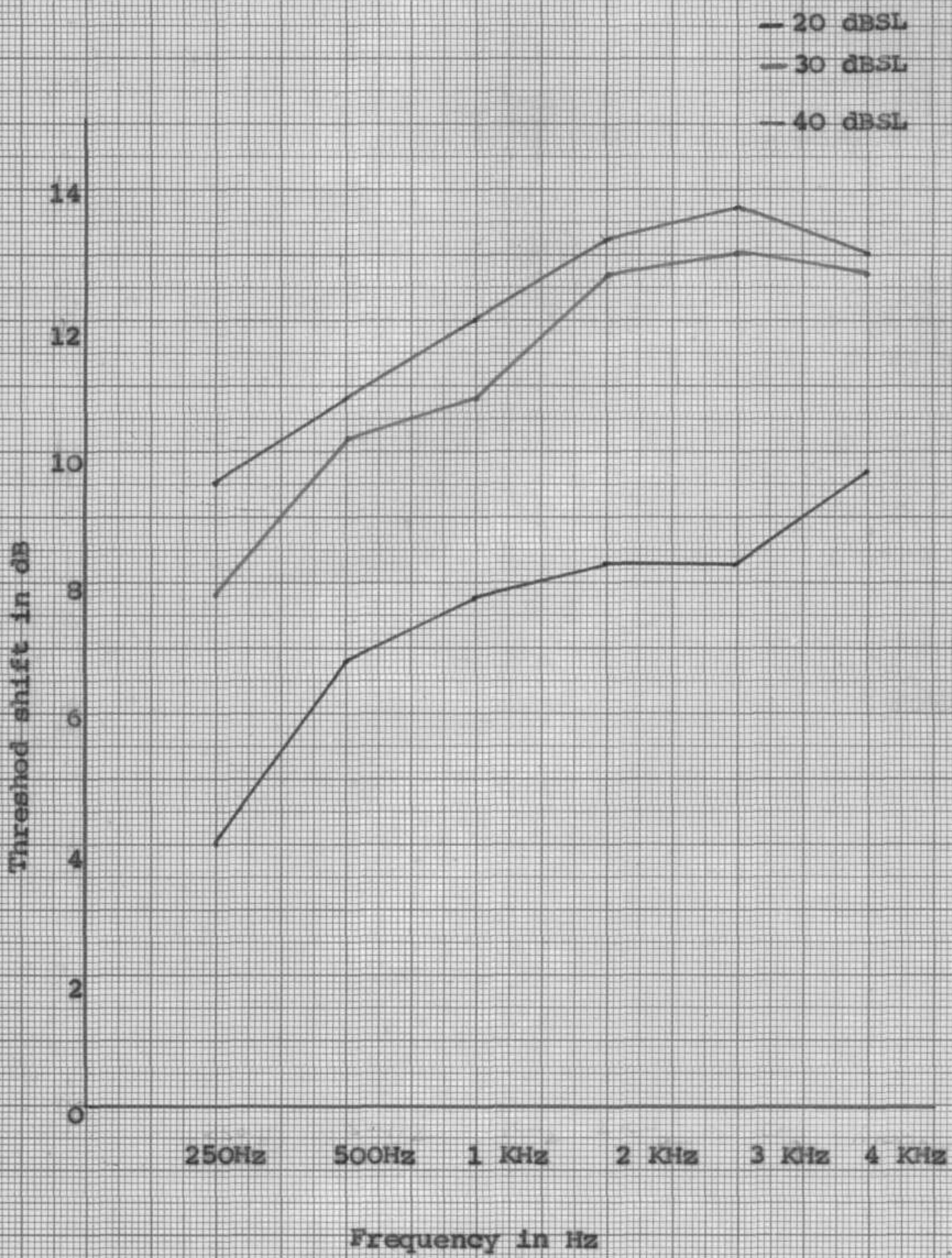
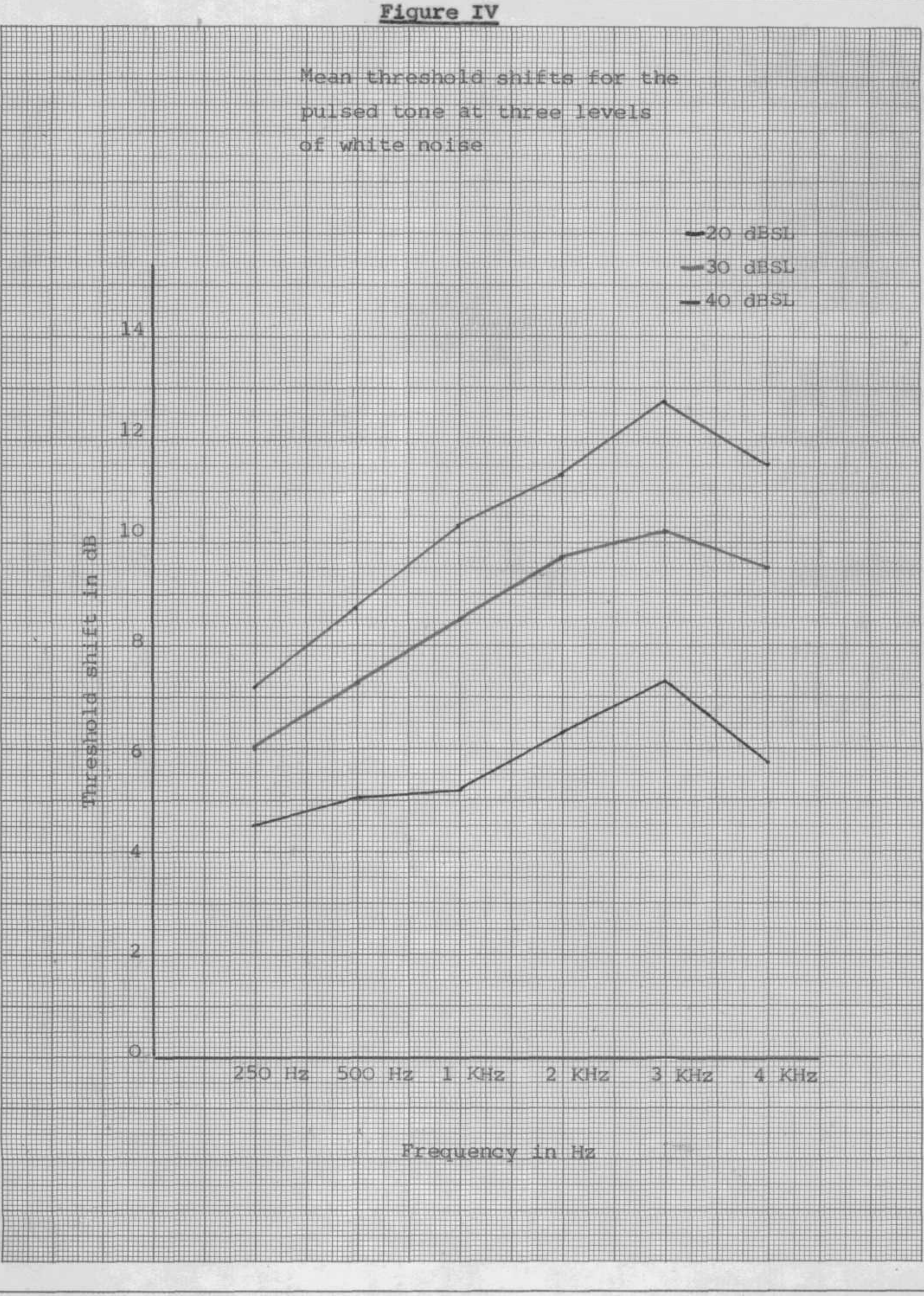


Figure IV



Mean threshold shifts for the pulsed tone at three levels of white noise

However, the interaction of the noise levels and the test frequency was found insignificant.

The effect of narrow band and wide band was studied in general, there was found a significant difference at .01 level. Statistical analysis also reveals that there is significant difference in the interaction of test frequencies and type of noise ratio. This is indicated in Table 4.

The central masking effect increases as the noise level increases irrespective of the type of noise and this increase in the threshold was found highly significant at .01 level. (Table 4).

When the interaction of the threshold shifts for 3 levels of narrow band noise and white noise was explored there was found a significant variation in the shift produced by these two types of noise at .01 level (Table 4).

Comparative study of the two experimental groups:

Four way analysis of variance was used when the results of the two experiments were compared.

The mean threshold shifts of the means at three levels of narrow band and white noise for continuous and pulsed tones are sepresented graphically in Figure V.

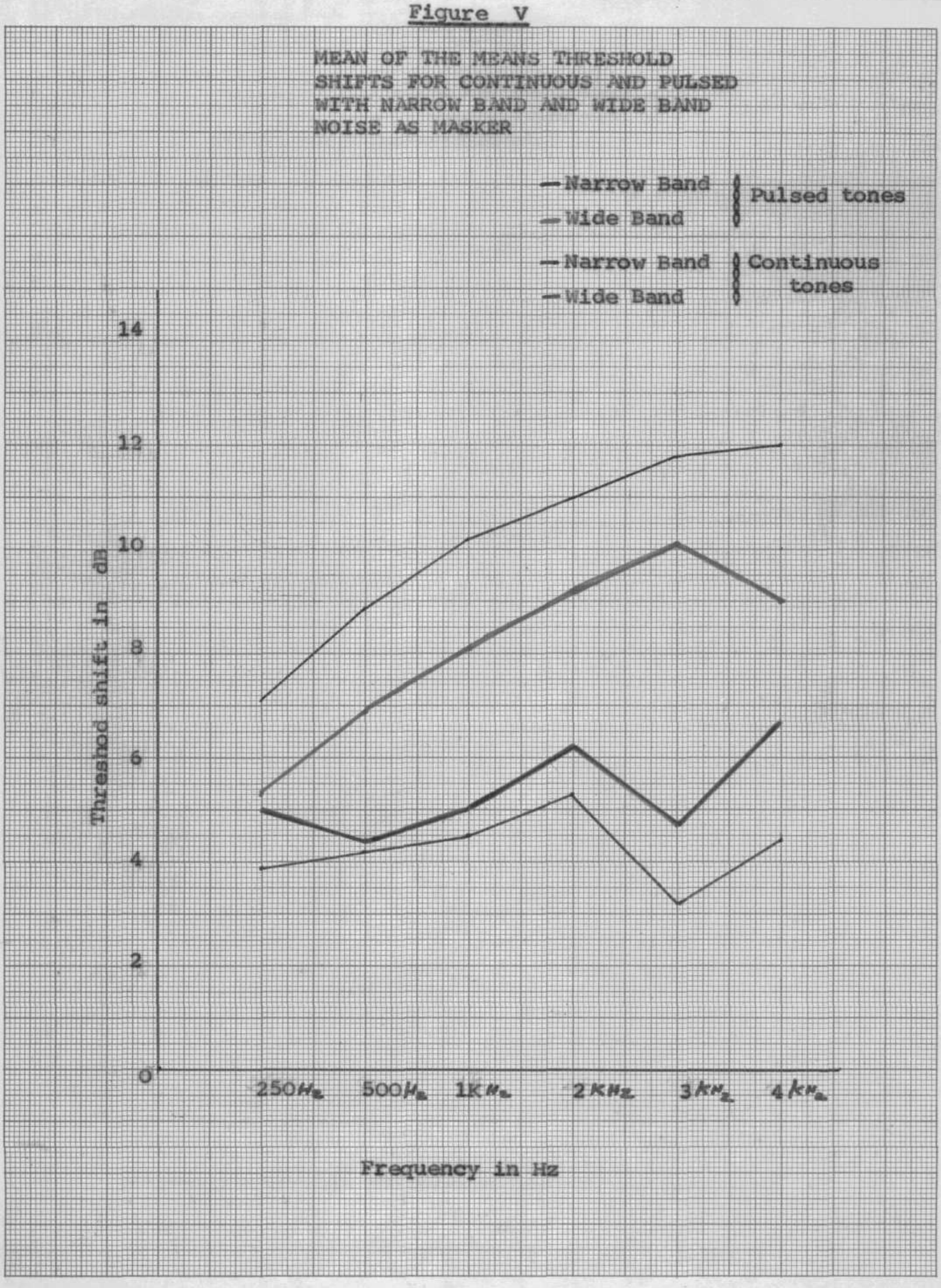
Table 5 gives the statistical values for all the variables studied in the two experimental groups.

Table 4. Results of 3-way analysis of variance for the effect of continuous Narrow band and wide band masker sensation levels, frequencies and their interaction effect

Source of variation	SS	dy	MS	F
Due to frequencies	73888.9	5	14777.78	8.65
Due to type of noise	36736.1	1	36736.1	21.50
Due to Noise levels	118893.1	2	59446.5	34.80
Frequency X noise levels	2290.3	10	229.3	0.13*
Frequency X type of noise	84447.3	5	16889.5	9.89
Error	17079.2	10	2707.92	

*Significantat 0.05 level

Figure V



MEAN OF THE MEANS THRESHOLD SHIFTS FOR CONTINUOUS AND PULSED WITH NARROW BAND AND WIDE BAND NOISE AS MASKER

When the analysis of the threshold shifts obtained at each frequency for pulsed and continuous tone was done there was found a statistically significant difference at .01 level between the shifts produced for the above test tone.

The variation due to change of tones (continuous and pulsed) was found statistically significant at .01 level of confidence.

The F ratio for the type of noise (Narrow band and wide band) shown in Table 5 was statistically significant at .01 level. The interaction effect between the type of noise ratio and the type of test tone was significant at 0*01 level (Table 5).

Statistical analysis shows that the main effect on threshold shift produced by each level of noise for every frequency as the level of noise increases was found significant at .01 level for both the experimental tones. Statistical analysis also reveals a significant difference in the interaction of noise levels and the test tone (continuous/pulsed) and was found significant at .05 level.

Test Re-test Reliability:

The scores of 10 subjects (5 from each group) in the test and re-test session were computed statistically using the correlation coefficient. The correlation coefficient in experimental group I was of .79 and in experimental group II .78.

Table 5: Results of 4-way analysis of variance for the effect of continuous and pulsed narrow band and wide masker sensation levels, frequencies and their interaction effect

Source of variation	SS	dy	MS	
Due to frequencies	51874.8	5	10374.96	8.23
Due to type of noise	39762.0	1	39762	31.5
Due to noise levels	156252.8	2	78126.4	62.01
Due to continuous & pulsed stimuli	316542.7	1	316542.7	251.2
Continuous & pulsed X Noise levels	102608.8	2	51304	4.7
Continuous & pulsed X type of noise	219099.6	1	219099.6	173.9
Continuous & pulsed X frequencies	206986.8	5	41397.36	32.8
Error	67991.3	54	1259.9	

Thus indicates a higher reliability of the test.

Discussion:

The present study yielded 4 to 7 dB and 7 to 12 dB threshold shift for the continuous tone and pulsed tone when the masker was a narrow band noise. And 3.6 to 5.5 dB and 5 to 10 dB for continuous and pulsed when wide band noise was used as the masker. This indicates that a narrow band has greater central masking effect than white noise. These results are in agreement with the results of Snyder (1973) who proved that as the bandwidth of the masker was narrowed the central masking tended to become significantly greater. Further Fletcher (1940) reported that only a small part i.e., the critical band of a wide band masker contributes to the masking of a tone.

Zwicker et al (1957) also showed, while explaining critical band that when the frequency band of the noise is reduced close to the test frequency greater shift in threshold was noticed as a result of central masking. This answers the first question of the present study that there is a definite difference in the threshold shift produced by narrow band and wide band. The narrow band noise produces greater threshold shift than wide band noise.

Dirks and Malmquiet (1965) showed greatest threshold shift when both tone and noise were pulsed.

Zwislock, Buning and Glantz (1968) showed greater threshold shift as much as 11 d B where tone and the masker ware pulsed.

The same effect is also evident in the present study where greater threshold shift was noticed for the pulsed tone.

This indicates that the threshold shift is different for different types of stimuli and thus answers question four.

When Zislock (1953) reports a threshold shift of 5 dB, Liden et al (1959) gives a shift of 5 to 15 d3 and studebaker (1962), Dirks and Dirks and Malmquist (1964) reports an increas of to to 12 dB. Later Snyder (1973) suggests that the shift shows that the threshold shift varies from 4 to 7 dB in the continuous tone and 5 to 12 dB for pulsed tone,

As the threshold shift for the continuous tone is with in 7 dB a uniform correction factor of 5 dB may be recommended in clinical practice.

For the pulsed tone variations are greater. The analysis of variance shows that the threshold shift as frequency increases was significant when pulsed tone used. This is in agreement with the study of Sherrick (1961) who had also shown that central masking effect increases with the test frequency for pulsed tone stimuli. This suggests the use of different values as correction factor for central masking in clinical practice whenever pulsed tone is used. Thus the results of the present study are comparable to those of similar studies conducted elsewhere. This answers the fifth question of the present study.

Though 5 dB can be used as a single value for the correction of central masking for continuous tone in routine clinical audiometry, audiologists must be aware that the central masking effect is frequcny dependent whenever pulsed stimuli are used in clinical audiometry. An attempt has also been made to form a correction chart for the possible central masking whenever pulsed stimuli is employed. The values are given in tabular form at the appendix V.

From this study it is also noted that central masking was greater for high frequencies and the same results were reported by Sherrick and Albernaz (1961). this gives a conclusion that central masking could not be produced by aural reflex.

When effect of noise levels on the threshold shift was studied we found that irrespective of the type of noise there is a significant increase in the threshold shift as noise level increases. Further this differential effect was greater for the narrow band noise than with wide band noise. Billings and Bradley (1977) also obtained similar results when he used 3 levels of masker intensities.

The threshold shift due to any peripheral origin is clearly ruled out as the levels of noise were not high enough,

When 10 subjects were retested after a lapse of 15 days, they yielded similar results giving a correlation co-efficient value of .78 and .79 indicating that central masking is fairly constant and is a reliable factor.

The results of the present investigation are also in agreement with the findings of other similar studies that throw light on this area. This information would be a useful guide line for the clinician. This may also become a useful tool in the investigation of normal and pathological auditory system.

CHAPTER V

SUMMARY AND CONCLUSIONS

Central masking phenomenon though reported by Wegel and Lane in 1924 it was not been studied elaborately. Only few studies have been reported so far on this area. The present study is therefore aimed at estimating the central masking factor on threshold of hearing in normal subjects.

A sample of 60 subject with an age range of 18 to 24 years were selected for the study. The subjects were than divided randomly into two experimental groups namely experiment I and experiment II. In experiment I the tone and the masker used were continuous where as in experiment II both were pulsed.

After establishing the hearing thresholds for pure tones, both continuous and pulsed and narrow band noise and wide band noise, both continuous and pulsed, the better ear was selected for masking in two groups. Three levels of noise, 20 dBSL, 30 dBSL and 40 dBSL respectively were used to study the effect on the threshold of hearing in the centra-lateral ear. The test frequencies used were 250 Hz, 500 Hz, 1 KHz, 2 KHz, 3 KHz and 4 KHz. The central masking effect was evaluated by comparing the unmasked thresholds with masked thresholds for narrow band and wide band noise separately.

The data obtained was then analysed statistically to find the significance of these results when, compared to other study results. The values to be used as correction for central masking are given in Tabular Form (Appendix)

The results, on analysis, indicate that narrow band is an efficient masker for pure tones than wide band noise, thereby supporting the view point of Fletcher (1940) and Zwicker (1957) and the critical band hypothesis,

Though the present study limit the use o5 centra^ masking effect as a correction factor in clinical masking we Fervently believe that it may become an indirect tool in the investigation of the normal and pathological auditory nervous system.

Suggestation for the further study:

1. Further research may be conducted on clinical group the study the behaviour of the pathological ears.
2. Study may be repeated using Bone conduction receivers.
3. Change of central masking using insert receiver and using higher sensation levels may be studied.
4. The effect of continuous noise on pulsed tone and pulsed noise on continuous tone may also be explored.

5. Change of threshold shift by varing the frequency of the masker and keeping the frequency of the test tone constant may be studied for different audiometric frequencies.

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APPENDIX I

Sound pressure levels in the sound treated room at various frequencies

	Max. allowable noise levels in dBSPL re 0.0002 dy/cm	SPL value in the test room in - dB .0002 dy cm
C Scale	30	33
Octave bands:		
75 - 150 Hz	31	18
150 - 300 Hz	25	17
300 - 600 Hz	26	15
600 - 1200	30	9
1200 - 2400	38	11
2400 - 4800	51	10.5
4800 - 9600 Hz	51	10

APPENDIX II

Audiometer Calibration

Standards: I.S.O. (1964)

Audiometer: Madson Type OB 70

Notes: 1. Used 6 6.c.coupler, artificial ear (B&K type 4152) and Mx-41/AR ear phone cushion

2. B&K sound level meter type with External Filter (type 1613)

3. Dial setting was at 60 dBHL.

A Pure Tones:

Frequency in Hz	dB S.P.L with ref. 0002 dy/cm^2	Measured output with ref. 0002 dy/cm^2
250 Hz	25.5	85.5
500 Hz	11.5	71.5
1 KHz	7.0	67.0
2 KHz	9.0	69.0
3 KHz	10.0	70.0
4 KHz	9.5	69.5

Narrow band noise

Centre frequency in Hz	dB S.P.L re- 0002 dy/ cm^2	Measured output
250 Hz	25.5	85.5
500 Hz	11.5	71.5
1 KHz	7.0	67.0
2 KHz	9.0	69.0
3 KHz	10	70.0
4 KHz	9.5	69.5

wide Band noise

	19.5	79.5

APPENDIX III

RECORD SHEET

Name:
Age :
Occupation:
Sex:
History:

THRESHOLD SENSITIVITY FOR PURE TONES

Ear	250 Hz	500Hz	1 KHz	2 KHz	3 KHz	4 Kz
L						

THRESHOLD SENSITIVITY FOR N.B. & W.B. NOISE

Ear	250 Hz	500 Hz	1 KHz	2 KHz	3 KHz	4 KHz	W.B
R/L							

NARROW BAND MASKING NOISE

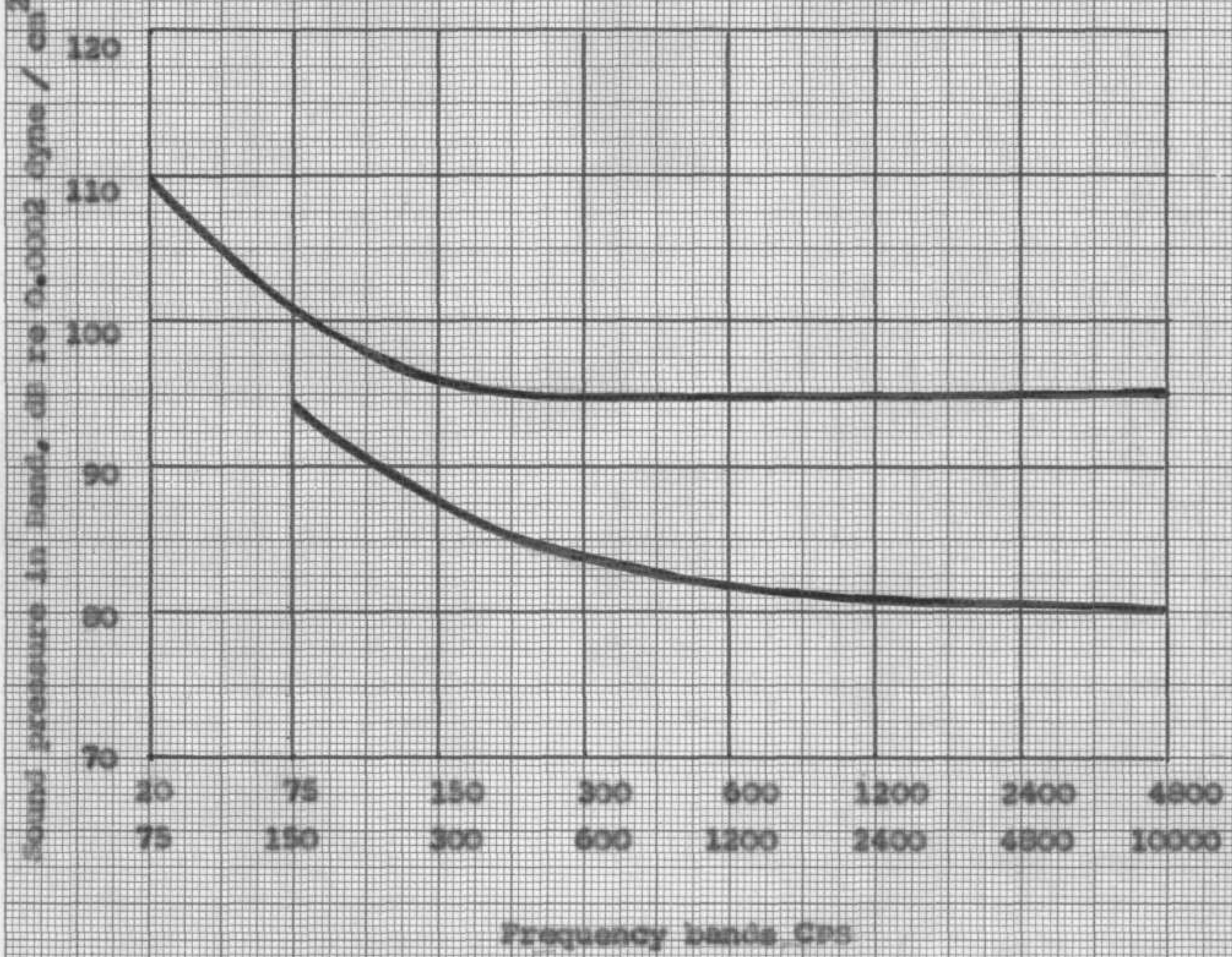
Noise levels	250 Hz	500 Hz	1KHz	2 KHz	3KHz	4 KHz
20 dB SL						
30 dB SL						
40 dB SL						

WHITE BAND MASKING NOISE

Noise levels	250	500	IK	2 KHz	3 KHz	4 KHz
20 dB SL						
30 dB SL						
40 dB SL						

APPENDIX IV

*Damage-risk criterion for steady noise
and for life time exposures.



* From Walter A. Rosenblith and Kennth M. Stevens, Handbook of Acoustic Noise Control, Vol. II, Technical Report 52-204, Wright Air Development Center, June 1953.

APPENDIX V

Correction for central masking for pulsed tone when a pulsed narrow band and wide band noise is, used as a masker

Frequency in Hz	Narrow Band Noise	Wide Band Noise
250 Hz	7	5
500 Hz	9	7
1 KHz	10	8
2 KHz	11	9
3 KHz	12	10
4 KHz	12	9