Original Research Article

Effect of aging and signal frequencies on masking level differences

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ABSTRACT

Background: The typical masking level differences (MLD) paradigm involves homophasic and antiphasic masking conditions. Objectives of the study were to develop homophasic and antiphasic stimulus, to find out the effect of signal frequency and age on MLD when all the antiphasic conditions are compared to the homophasic S_0N_0 and $S_\pi N_\pi$ condition and to find out effect of interaural time delay of stimulus on aging.
Methods: 90 participants were divided into 3 groups of young adults, early presbycusic adults and geriatric presbycusic adults. Various stimuli were developed and presented. The MLD were obtained using homophasic and antiphasic stimuli at 4 frequencies 250, 500, 1000 and 2000 Hz. Subsequently, these were statistically analyzed using ANOVA and paired t-test.
Results: All the conditions used in the study had some condition with and without significant differences. However, at 500 Hz in S_0N_0 homophasic condition all four antiphasic conditions among groups MLD and Interaural time delay between groups showed significant differences were present.
Conclusions: From these findings, the best frequency is 500 Hz as the homophasic S_0N_0 baseline condition. A significant difference between the groups indicated presence of age-related effect on MLD and interaural time delay, suggesting that age related changes can be observed in the binaural hearing and temporal processing of the signals and can be measured using MLD.

Keywords: Masking level differences, Binaural masking level difference, Masking, Geriatric hearing, Homophasic antiphasic sound stimulus

INTRODUCTION

The word "masking" can be defined as the threshold shift, where threshold of a sound is raised due to the presence of another sound. First, the unmasked threshold of the test stimulus is determined and recorded. This unmasked threshold becomes the baseline. Next, the masker is presented to the subject at a fixed level. The test stimulus is then presented to the subject and its level is adjusted until its threshold is determined in the presence of the masker. This level is the masked threshold.[1]

Binaural threshold may be higher than the monaural so that there is some kind of inhibition of one ear on the other. This is known as the Interaural Inhibition. This interaural inhibition can be shown when a low frequency tone is masked by intense noise.[2]

One method of assessing binaural hearing performance is to compute the improvement in tone detection thresholds when interaural differences are introduced in the stimuli, known as the BMLD. Specifically, a BMLD can be measured when comparing the threshold for an interaurally in-phase tone that is detected in an interaurally in-phase noise (called N_0S_0) with the

threshold for an interaurally out-of-phase tone that is detected in an interaurally in-phase noise (called $S_\pi N_0$) or interaurally in-phase tone that is detected in an interaurally out-of-phase noise (called $S_0 N_\pi$). A BMLD exists when the $N_0 S_\pi$ or $N_\pi S_0$ threshold is lower than the $N_0 S_0$ threshold, demonstrating the benefit of binaural processing. An understanding of age-related changes in the BMLD and in the neural mechanisms that may contribute to these changes may help to explain some of the difficulties that older adults experience when trying to understand speech in noisy environments.[3]

This binaural advantage is demonstrated by the contrived laboratory paradigm of masking level differences (MLD).[2,4,5] It is the difference between the recognition performances of binaural conditions in which the phase of either the signal (S) or the noise (N) (masker) is manipulated.[6]

The MLD requires auditory processing from the periphery to cortical areas. A healthy auditory periphery and brainstem codes temporal synchrony, which is essential for the ABR. Threshold differences, require engaging cortical function beyond the primary auditory cortex.[7]

Phase locked neural activity has been recorded in brainstem pathways generating the ABR, FFR, and pathways involved in BMLD perception.[8] The BMLD provides a measure of individual's ability to segregate sounds based on spatial position and improve their detectability in the presence of interfering sounds. The MLD provides information on binaural interaction regarding temporal and spatial processing ability and can indicate dysfunction below the cortex in the brainstem area of the CNS. The values have been previously established to be affected by various factors such as type of noise, intensity of noise, etc. The average BMLDs of Mandarin tones are smaller than the average BMLDs of Mandarin tones.[9] Similarly, a study reported that for the 20-Hz wide masker, the BMLD, i.e., threshold difference between diotic and dichotic signal, increased with signal duration and, for the 300-ms signal, the BMLD was larger with 50-ms rather than 6-ms ramps. However, these signal parameters hardly affected the BMLD for the 200-Hz wide masker.[10]

Previous studies which were carried out in the elderly using antiphasic dichotic conditions the extent of binaural unmasking have found only small age effects.[8,11,12] Studies that included an old group with audiometric thresholds matched to the thresholds of young subjects, or that met the experimenter's criterion for normal hearing.[13-15] Young subjects performed about 1 dB better than old subjects, but this age effect was not significant.

There is a need of test battery approach and a wide sampling of central auditory function to describe the integrity of central auditory nervous system of geriatric subjects with normal hearing in Indian context. By measuring the MLD in an aging population in the earliest stage of presbycusis, ability to use interaural differences to unmask signals in noise can be assessed. Temporal processing deficits have been previously demonstrated in human aging subcortical and cortical studies.[16-18] The BMLD depends on precise encoding of interaural timing and level differences; therefore, we predicted that age-related temporal processing deficits may be visible in BMLD thresholds.

The current study was aimed at developing adequate test stimuli and subsequently study effect of aging, stimulus frequency on MLD.

The objectives of the study are to develop homophasic and antiphasic stimulus to measure MLD. Subsequently, to find out the effect of signal frequency on MLD; of age on MLDs when all the antiphasic conditions are compared to the homophasic $S_0 N_0$ condition; of age on MLDs when all the antiphasic conditions are compared to the homophasic $S_\pi N_\pi$ condition and lastly, to find out effect of interaural time delay of stimulus on aging.

METHODS

Research design

Descriptive research with ex-post facto design used for the study.

Sampling

Purposive sampling technique used in the study.

Participants

The participants were categorized into three groups. Group 1 consisted of 30 young adults (mean age=22.3 years, SD=1.6 years, age range=20-25 years). The participants were recruited from the institute. Group-2 consisted of 30 early presbycusic adults (mean age=54.6 years, SD=1.3 years, age range=50-60 years). Lastly, group 3 consisted of 30 geriatric adults (mean age=65.5 years, SD=3.2 years, range=61-70 years). Participants of these two groups were selected from locality and the patient's guardian.

Inclusion criteria for all the groups

All the participants had normal hearing sensitivity across the audiometric range (Rt. Ear mean PTA=17.19 dBHL, SD=4.254; Lt. ear mean PTA=17.66 dBHL, SD=4.101), normal middle ear functioning with type "A" tympanogram, had normal otoscopy findings as consulted by ENT specialist. Group-2 and 3 were ruled out to not having any neurological impairment as well as perceptual and cognitive impairment for all the groups.

Consent

Written consents was obtained from all the subjects for participation in the study after a detailed explanation.

regarding the study. The institutional ethics committee approved the study.

Instrumentation

An otoscope (Heine beta ® 200), MAICO MA 53 dual channel diagnostic audiometer, telephonic TDH-39 supra-aural headphones. An Apple iMac OS X (version-10.14) with AVID pro tools 2020.3 software, in studio setup was used to generate and record the signal and noise stimulus as required based on acoustic features of the sound. The recorded stimulus was copied in the Lenovo audio player model V203 that was connected to the audiometer by the use of stereo-to-mono adaptor jack.

Test environment

A two-room setup audiometric room was used. The environmental state of the test room was met with the current American national standard institute for background noise (ANSI S3.1-1999, R2003, R2018).

Procedure

The current research was conducted from December 2019 to August 2020 at the Ali Yavar Jung National Institute of Speech and Hearing Disabilities (Divyangjan), Regional Centre, Kolkata. It was carried out in two phases. Phase 1 was development of the test stimuli and 2 was administration of the stimuli to obtain data.

Phase I

Stimulus selection

To measure binaural unmasking, there is always a baseline condition and a comparison condition. In this study, two homophasic baseline conditions were explored first, S_0N_0 were the signal and masker were presented diotically; and second, $S_\pi N_\pi$ were the signal and masker presented to one ear which was both 180° out-of-phase relative to signal and masker presented to the other ear.

In the comparison condition, 1. $S_\pi N_0$-The masker was presented diotically but the signal presented to one ear was phase-shifted by 180° relative to the signal presented to the other ear, 2. S_0N_π-The signal was diotic, but the polarity of the noise was reversed, 3. Two other dichotic conditions were also used having an interaural time delay in the masking noise, 4. S_0N_τ-Where $_\tau$ is the interaural delay in milliseconds, an interaural delay of 1ms was introduced in the masking noise but not in the 500-Hz signal and, 5. $S_\pi N_{\pi\tau}$-The 500-Hz pure-tone signal and the masker were each be phase-reversed with a 1-ms time delay in the masker but not in the signal.

The 250, 500, 1 and 2 kHz pure tone signals were presented in narrowband burst masking noise at 52 dBSPL in above conditions. The delay $_\tau$ in the masking noise was 1 ms and equal to half the period of pure-tone signal.[21-26]

Phase II

Stimulus development

Used signal and noise stimulus were used to develop the stimulus conditions, which were generated using stimulus generator plug-ins from AVID pro tools 2020.3 software developed by Avid Technologies Inc.

In the software pure tone signal as well as noise spectrum of particular frequency as well as intensity level were generated.

After completion of arranging all the stimulus conditions in layer based on criteria, all the conditions were exported by rendering in a .WAV audio format with the sampling rate of 48 kHz and bit rate of 16 bit. These entire exported stimulus conditions were saved in an audio player (model-Lenovo V203).

Phase III

Stimulus presentation

Stimulus was presented by connecting the audio player with the dual channel audiometer (MAICO MA 53). Stimuli were presented through high-definition headphones in a two-room setup audiometric room. The 2 observation intervals were presented, following by a 500-msec separation between intervals. Subjects have to indicate the interval containing signals by pressing response switch.

A two-interval, two-alternative forced-choice (2/2AFC) procedure was employed. Four signal levels spaced 6 dB apart were employed. The masking noise and the tone were gated on and off simultaneously (200-msec duration with 10-msec rise-decay time).

Phase IV

Data recording

Thresholds for the baseline homophasic S_0N_0 and $S_\pi N_\pi$ conditions, and antiphasic $S_\pi N_0$, S_0N_π, S_0N_τ, and $S_\pi N_{\pi\tau}$ dichotic conditions were recorded from the all subjects from all the groups.

Statistical analysis

The raw data was subjected to statistical analysis. Mean and standard deviation were calculated by using statistical package for social science (SPSS) software (version-27). An analysis of variance (age x dichotic condition) was carried out for the checking variation in MLD values among the three groups in both the homophasic condition. Paired sample t-test was carried out to find the variation in MLD values between the individual groups as well as interaural time delay.

Statistical analysis was carried out in three sub-stages as: 1. All the collected data were analyzed using an analysis of variance to check variation in MLD values among the three groups in both the homophasic condition, 2. From the analysis, the collected results were plotted in 2D line diagram and the best frequencies of the MLD values were calculated and, 3. After finding out the best frequency where MLD values are significantly better in all the groups, paired sample t-test was carried out to find out the variation in MLD values between the individual groups and interaural time delay at that best frequency condition.

RESULTS

Demographic

The study included following demographic (Table 1).

Table 1: Demographic details of subjects included in the study.

Parameters	Group 1	Group 2	Group 3
No of participants	30	30	30
Mean age (years)	22.3	54.6	65.5
SD	1.6	1.3	3.2
Age range (years)	20-25.	50-60	61-70
Clinical characteristics	Young normal adults	Early presbycusic adults	Geriatric adults

Stimulus

The first objective was to develop the stimulus, which was done successfully as described in the method. The same stimulus was used in testing.

Homophasic S_0N_0 condition

Analysis of variance was done at 250, 500, 1000 and 2000 Hz difference of all the four antiphasic conditions i.e., $S_\pi N_0$, S_0N_π, S_0N_τ and $S_\pi N_{\pi\tau}$ from homophasic S_0N_0 among the three groups. $F_{(tabulated)}$ value is the value of F at α=0.05 level of significance (95% confidence interval), which was 3.106 with the degree of freedom (df)=2,87 and remained same for all the frequencies in this condition.

F (observed) values obtained tabulated below for 250 Hz.

Table 2: Analysis of variance at 250 Hz.

Variables	N	df	Mean	$F_{(observed)}$	$F_{(tabulated)}$
$S_\pi N_0$	30	2,87	2.70	2.04	
S_0N_π	30	2, 87	2.27	2.91	3.106
S_0N_τ	30	2, 87	1.91	10.002	
$S_\pi N_{\pi\tau}$	30	2, 87	2.18	5.30	

While, there was a significant difference in S_0N_τ, $S_\pi N_{\pi\tau}$ conditions, whereas, there was no such significant difference in $S_\pi N_0$, S_0N_π conditions.

Similarly at 1000 Hz, there was a significant difference among the three groups in the $S_\pi N_0$ and S_0N_π conditions, whereas, there was no such significant difference in S_0N_τ and $S_\pi N_{\pi\tau}$ conditions. At 2000 Hz there was a significant difference in the $S_\pi N_0$, S_0N_τ and $S_\pi N_{\pi\tau}$ whereas, there was no such significant difference in S_0N_π condition.

Contrastively, significant differences were observed in all the four antiphasic conditions at 500 Hz. Disjunctively, in children this has not been seen to hold true. A study reported there was significant difference between test results in $S_\pi N_0$ conditions of the good and poor performing school going children, while no differences were found both in S_0N_0 conditions and the final result of MLD.[27]

Homophasic $S_\pi N_\pi$ condition

This was carried out similarly, except that $S_\pi N_\pi$ homophasic condition was used and the results were seen to vary. At 250 Hz, there was a significant difference in S_0N_π, S_0N_τ and $S_\pi N_{\pi\tau}$ conditions. There was a significant difference in antiphasic $S_\pi N_0$, S_0N_τ and $S_\pi N_{\pi\tau}$ conditions at 500 Hz. $F_{(observed)}$, values obtained at 1000 Hz showed a significant difference in the $S_\pi N_0$, S_0N_π and $S_\pi N_{\pi\tau}$ conditions. Lastly, at 2000 Hz, there was a significant difference only in the S_0N_π and $S_\pi N_{\pi\tau}$ conditions.

From the above results, it was found that significant differences were present in all the MLD values measured in all antiphasic conditions only at 500 Hz at homophasic condition S_0N_0. However, in homophasic $S_\pi N_\pi$ condition, no particular frequency was found which shows a significant difference in all antiphasic conditions.

When MLD was compared between group 1 and 2 and between group 1 and 3 using paired t-test. The overall results indicated that there was significant difference between the three groups in both the antiphasic conditions suggesting significant effect of age on MLD.

These results suggested that 500 Hz is the best frequency when homophasic condition S_0N_0 is used as the total mean score of MLD values were significantly higher in 500 Hz at all antiphasic conditions than the other frequencies, similar findings have been reportedly in previous literatures.[21,22,13]

Similar findings were reported by another study using electrophysiological measures. Using cortical auditory-evoked potentials (CAEPs), Eddins and Eddins obtained behavioural and neural thresholds to 500- and 4,000-Hz tones presented in 50-Hz wide maskers in N_0S_0 and N_0S configurations.[28] The younger participants in their study had significantly larger perceptual BMLDs and larger CAEP threshold differences between configurations than

the older normal hearing and older hearing-impaired participants for the 500-Hz tone but not for the 4,000-Hz tone. The authors concluded that the age-related reductions in BMLDs are due to decreased ability to benefit from the temporal fine structure cues that would be available in the 500-Hz tone but not the 4,000-Hz tone (due to phase-locking limits of the auditory system).

Interaural time delay

Measuring the effect of interaural time delay on aging was one of the objectives of this study. Statistically analysis of interaural time delay between group 1 and 2 and group 1 and 3 showed significant difference in both the cases.

MLD values were calculated by comparing homophasic S_0N_0 condition with the antiphasic S_0N_τ and $S_\pi N_{\pi\tau}$ conditions. In antiphasic S_0N_τ condition the pair difference of mean MLD values between group-1 and group-2 was found to be 7.200, in the $S_\pi N_{\pi\tau}$ condition the pair difference of mean MLD values between group-1 and group-2 was found to be 8.700. The significant values from the paired t-test have been mentioned in table IX.

Table 3: Paired t-test for equality for means of MLD values between group 1 and group 3 when homophasic S_0N_0 condition was compared with antiphasic $S_\pi N_0$ and S_0N_π conditions.

Paired t-test				
MLD values	**95% CI of the difference**		**T**	**df**
	Lower	**Upper**		
S_0N_τ group1-S_0N_τ group 2	5.84690	8.55310	10.883	29
$S_\pi N_{\pi\tau}$ group1-$S_\pi N_{\pi\tau}$ group 2	7.46291	9.93709	14.383	29

In antiphasic S_0N_τ condition the pair difference of mean MLD values between group 1 and group 3 was found to be 1.030, in the $S_\pi N_{\pi\tau}$ condition the pair difference of mean MLD values between group 1 and group 2 was found to be 8.800.

DISCUSSION

The present result has contributed to find the changes that occur in binaural hearing and temporal processing with the aging. These findings help us understand how aging affects binaural hearing. Subsequently it allows us to be cautious regarding the same in clinical practices during assessment and intervention.

Figure 1 indicates the frequency wise distribution of total mean MLD values of all three groups in each antiphasic condition. These results suggested that 500 Hz is the best frequency when homophasic condition S_0N_0 is used, as the total mean score of MLD values were significantly

higher in 500 Hz at all antiphasic conditions than the other frequencies.[29,30] This is supported by Jeffress et al reported similar findings.[32]
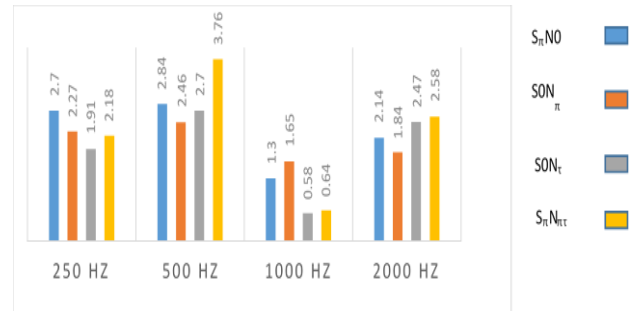

Figure 1: Bar diagram of comparison of mean MLD values at each antiphasic conditions with the homophasic S_0N_0 condition in the entire tested frequency region.

Physiologically, the above findings are also supported by an animal study suggesting the neurons at inferior colliculus have band frequency near to 500Hz i.e., ranging from 300-800 Hz of signal frequency were highly sensitive in detection of in phase and out of phase signals.[33] Results of this study supported the findings of studies who investigated the age-related changes in binaural unmasking in young and geriatric subjects using the antiphasic $S_\pi N_0$ condition.[33,34]
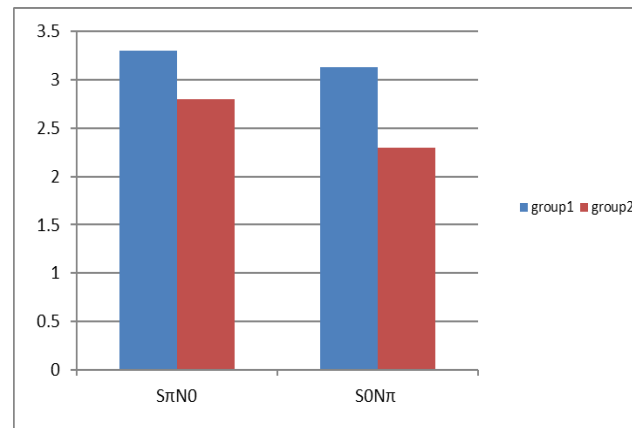

Figure 2: Bar diagram of comparison of mean MLD values of the two groups (1 and 2) in two antiphasic conditions $S_\pi N_0$ and S_0N_π.

There was a significant difference between group 1 and 2, when MLD values were measured in both the antiphasic conditions $S_\pi N_0$ and S_0N_τ with the homophasic condition S_0N_0 as can be seen in the graph above. Similar findings were seen in case of group 2 and 3 i.e., the mean MLD value of the young normal adults in antiphasic S_0N_τ condition was 8.53 dBHL whereas that of early presbycusic adults was 1.33 dBHL and in antiphasic $S_\pi N_{\pi\tau}$ condition 9.6 dBHL and 0.9 dBHL respectively. Revealing that there was a significant difference present between group 1 and 2 when MLD values in terms of

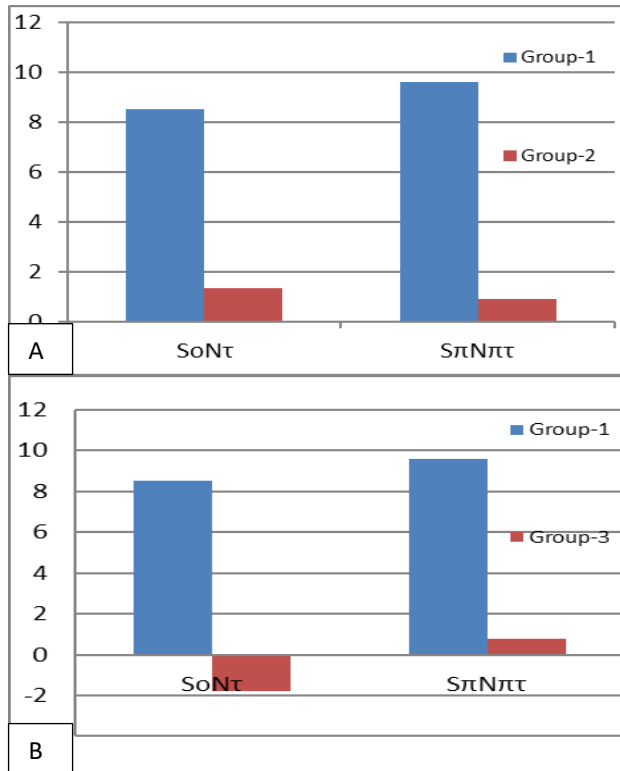ITD. The same can be seen in Figure 3 graphs A and B respectively.

Figure 3: Bar diagram of comparison of mean MLD in terms of ITD values of the two groups in two antiphasic conditions (A) S_0N_τ and $S_\pi N_{\pi\tau}$ and (B) S_0N_τ and $S_\pi N_{\pi\tau}$.

Results of this study also corelated with the findings of studies by Jerger et al who investigated the age-related changes in binaural unmasking in young and geriatric subjects using the antiphasic $S_\pi N_0$ condition.[19] Novak et al found that the group with assumed neural presbycusic had masking-level differences in noise that were significantly smaller than those for the other groups.[20] While Jerger et al demonstrated a successful use of 500 Hz for obtaining MLD values.[19]

Based on the findings of this study, it could be stated that there was a significant effect of age-related changes in MLD values when it was measured as a difference between homophasic S_0N_0 condition and antiphasic $S_\pi N_0$ and S_0N_π conditions respectively.[33,34] The findings were supported by Anderson et al on both behavioral and electrophysiological assessment of BMLD. This is also agreed upon by another study, which carried out both behavioural and electrophysiological assessment. They reported that in the behavioural experiment, aging reduced the magnitude of the BMLD. The magnitude of the BMLD was smaller for $N_0S_0-_{NnS0}$ threshold difference compared with $N_0S_0–N_0S_n$ threshold difference.[3]

However, early presbycusic adults showed higher MLDs in terms of ITD in S_0N_τ condition than $S_\pi N_{\pi\tau}$ condition

and the largest variation in MLD between the two groups occurred at $S_0N_0 -S_\pi N_{\pi\tau}$ than $S_0N_0 -S_0N_\tau$.

These findings established that temporal jitter of binaural system didn't vary as function of internal interaural delay in old subjects and interaural time delay had an effect on age related changes in MLD values as supported by previous literature.[26] They investigated age effects in MLD values in terms of ITD and temporal jitter and enumerated that age related changes were present in MLD values with the variation in ITD, also age effects was found in temporal jitter.[26] Hearing loss and aging are two subject factors that may also reduce the size of the BMLD. Listeners with hearing loss have relatively smaller BMLDs than those with normal hearing.[19,23] Age-related reductions in BMLDs are also well documented in studies comparing younger and older participants with clinically normal hearing.[21,25.26,33] This supported the evidence that binaural unmasking was largely attributable to interaural processing near 500 Hz where combined phase reversal and time delay resulted in the noise being effectively in phase, signal of course being out of phase.

These results establish that there is significant frequency variation of MLD values in terms of both phase relation and time-delay relation between young normal adults and early presbycusic adults in both the homophasic conditions. It also showed that there was very small amount of frequency wise variation in both the homophasic conditions between early presbycusic and geriatric adults. Similarly, there was a presence of significant frequency wise variation in both the homophasic conditions between young normal and geriatric adults.

The hierarchy of size of MLD found in dichotic conditions for the young group with the largest MLD being observed in the $S_\pi N_0$ condition, followed by the $S_\pi N_{\pi\tau}$ and S_0N_π condition. Whereas, the smallest MLD being observed in the S_0N_τ conditions.[5] Above all the findings were evidentiary that binaural unmasking was largely attributable to interaural processing near 500 Hz where the combined phase reversal and time delay resulted in the noise being effectively in phase and the signal, of course, being out of phase. Old subjects did not exhibit the hierarchy of size in MLD like the young subjects, and the greatest age effects were found in the dichotic conditions that resulted in the largest MLDs for the young subjects.[21] The results of this study suggested that, larger MLD values in terms of ITD also could be obtained when MLD values were calculated using homophasic $S_\pi N_\pi$ and antiphasic $S_\pi N_{\pi\tau}$ conditions.

In case of homophasic $S_\pi N_\pi$ condition, as seen in the Figure 4, the mean MLD values of comparison among the three groups in each antiphasic condition the $S_\pi N_\pi-S_\pi N_0$ MLD values were highest at 250 Hz and decreased with the increasing frequency. Whereas, no such significant variation was observed in $S_\pi N_\pi- S_0N_\pi$ MLD values across the frequency region. However, another significant trend

that was noted was that $S_\pi N_\pi$-$S_\pi N_{\pi\tau}$ and $S_\pi N_\pi$- $S_0 N_\tau$ MLD values were comparatively higher at high frequency like 1 and 2 kHz than low frequencies. These results were reminiscent of the MLD values obtained using the homophasic $S_0 N_0$ threshold.[20,21,27]
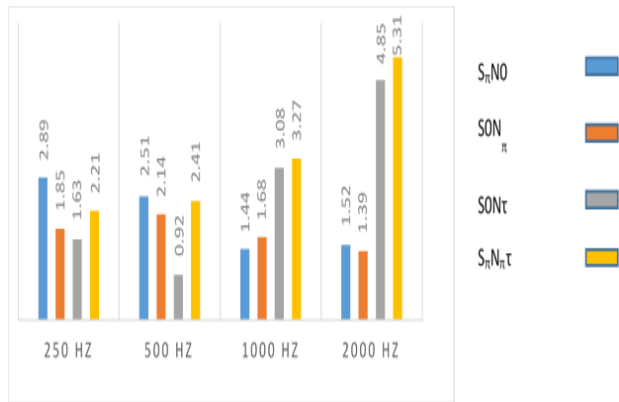

Figure 4: Bar diagram of comparison of mean MLD values at each antiphasic conditions with the homophasic $S_\pi N_\pi$ condition in the entire tested frequency region.

These findings suggest that the detection thresholds for pure tones were significantly higher under homophasic $S_\pi N_\pi$ and dichotic $S_\pi N_{\pi\tau}$ at frequency ranging from 1-3 kHz band frequency region were in consonance.[35,21]

Although according to critical bandwidth model of MLD, age-related differences in critical bandwidth were not sufficient to account for age-related differences in the pattern of MLDs rather these age-related differences and it could be further described in the function relating temporal jitter to internal delay.[5]

Frequency wise distribution of MLD values

There was a significant variation of mean $S_0 N_0$ -$S_\pi N_0$ MLD values and means $S_0 N_0$ - $S_\pi N_{\pi\tau}$ MLD values across the frequency region (250 Hz-2 kHz), where in all the three groups MLD values were maximum at 500 Hz and maximum variation was observed at 1 kHz for young adults and successively to early presbycusic and geriatric adults. This can be seen in Figure 5.

Similarly, in homophasic $S_\pi N_\pi$ condition, the variation of mean $S_\pi N_\pi$-$S_\pi N_0$ MLD values, where maximum variation was observed at 1 kHz from young to early presbycusic and geriatric adults. There was no such significant variation of MLD values among the three groups across the frequency range when homophasic $S_\pi N_\pi$ was used.[37,30] In case of $S_\pi N_\pi$ -$S_\pi N_{\pi\tau}$, MLD values across the frequency region (250 Hz-2 kHz), maximum variation was observed at 500 Hz and 2 kHz. Along with this there was a larger variation is observed values at high frequencies like 2 kHz than lower frequencies. Similarly, there was a presence of significant frequency wise variation in both

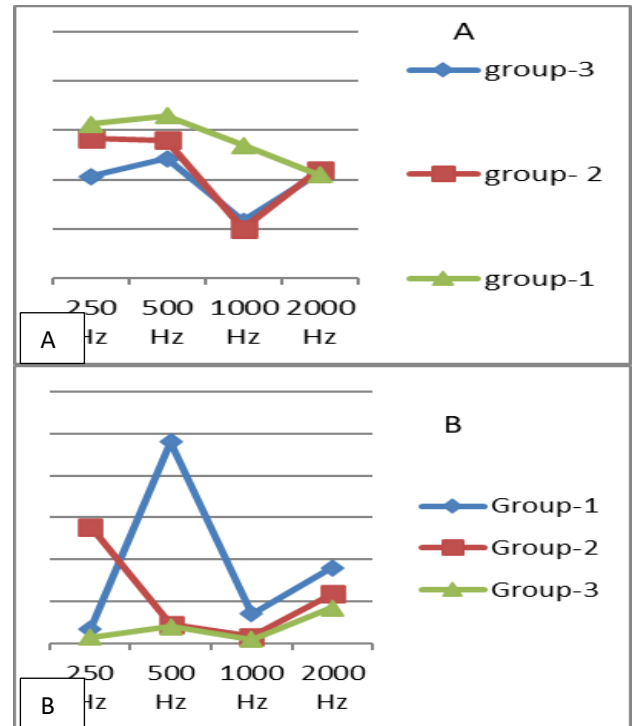the homophasic conditions between group 1and group-3.[6,21,38] This is visually evident in Figure 6 (A) and (B).

Figure 5: Line diagram of mean (A) $S_0 N_0$ -$S_\pi N_0$ and (B) $S_0 N_0$ - $S_\pi N_{\pi\tau}$ MLD values of the 3 groups.
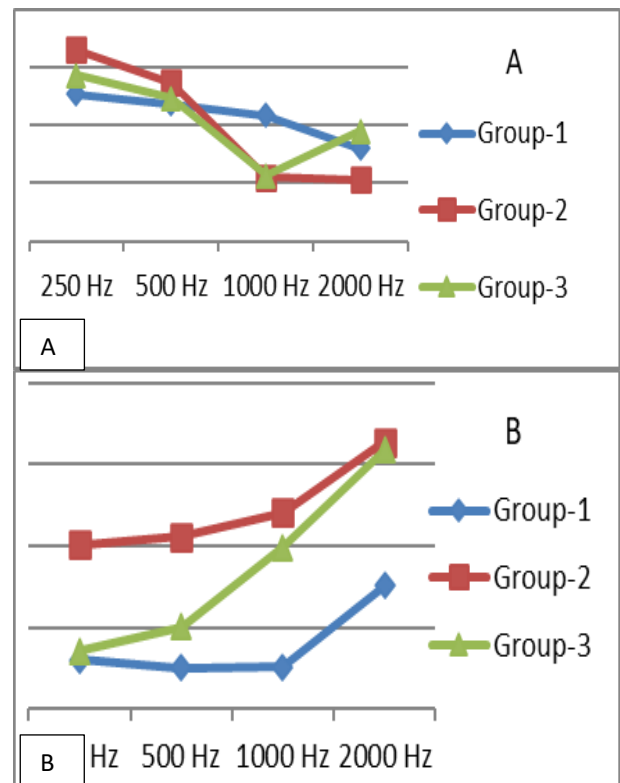

Figure 6: Line diagram of mean (A) $S_\pi N_\pi$ - $S_\pi N_0$ and (B) $S_\pi N_\pi$ - $S_\pi N_{\pi\tau}$ MLD values of the 3 groups.

CONCLUSION

The aim of the study was to develop test stimuli and subsequently find the effect of aging on BMLD. The results revealed that, there was a significant difference present at $\alpha=0.05$ among the three groups in MLD values measured in all the antiphasic conditions only at 500 HZ. In other frequencies, no such significant differences among the groups were found in all the antiphasic conditions. In frequencies like 1 kHz in both the homophasic conditions MLD values obtained using antiphasic S_0N_τ and $S_\pi N_{\pi\tau}$ conditions there were no such significant differences were present among the three groups, but at 2 kHz frequency there was a significant difference present among the three groups at $S_\pi N_\pi$ -$S_\pi N_{\pi\tau}$ MLD values. In baseline homophasic $S_\pi N_\pi$ condition it was found that MLD values are larger when interaural time delay of masker was presented at high frequencies, otherwise the MLD values in other antiphasic conditions are almost similar to that at homophasic S_0N_0 condition. From these findings, the best frequency was chosen as 500 Hz and the homophasic S_0N_0 baseline condition as the best baseline condition as well as the presence of effect of aging on MLD and ITD.

The present study suggests that age related changes can be observed in the binaural hearing and temporal processing of the signals and can be measured using MLD. To measure age related change in binaural hearing MLD can be measured using the antiphasic conditions consisting of interaural time delay between the masker noise and the signal. Apart from usual homophasic baseline S_0N_0 condition, also the homophasic $S_\pi N_\pi$ condition can be used to while measuring the interaural time delay of masker at high frequency. One of the important aspects when studying any phenomenon is to consider it from all perspectives. This study was carried out using a purely audiometric setup thereby from a subjective perspective. Consequently, a different perspective on defining BMLD could not be obtained. So further studies on BMLD using objective methods are needed.

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