Masking Level Difference in Adults: Comparison of MLDs at Low and High Frequencies

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Abstract

19 Masking Level Difference (MLD) is the difference in binaural thresholds between homophasic and antiphasic conditions. It is the most sensitive behavioral technique for assessing brainstem integrity and is also an effective tool in the audiological test battery. This made it imperative to design a compact disc (CD) based tool for clinical assessment and establishment of the normative data for MLD. The aim of the study was to compare masking level differences for low frequency i.e. 250 Hz & 500 Hz and high frequency i.e. 2000 Hz & 4000 Hz stimulation in normal hearing individuals. A nine minute and fifty one seconds long stimulus was generated using AuX (Auditory syntax). No significant difference between males and females (13 $p>0.05$) was observed. Significant difference was observed for both the pairs of low-frequency MLD (MLD 250 Hz – MLD 500Hz, $p<0.01$) and high-frequency MLD (MLD 2 kHz – MLD 4 kHz, $p<0.05$). Markedly significant differences were observed for the MLD thresholds obtained for 250 Hz - 500 Hz as well as 2 kHz - 4 kHz along with the MLD thresholds obtained for low frequency vs high-frequency conditions.Hence, the tool can be used to analyse MLD in the population although further studies would be required to establish its validity and reliability scores.

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INTRODUCTION

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1. The masking level difference (MLD), is the detection or recognition performance difference between binaural conditions in which the phase of either the signal (S) or the noise (N) (masker) is manipulated (Webster, 1951).
2. The difference in binaural thresholds between homophasic and antiphasic conditions is known as masking level difference (MLD) (Hirsch, 1948).
3. The procedure for masking level difference (MLD) can be done in one ear (monotically)**,** 4 or by presenting an identical signal and noise to both ears (diotically).
4. MLD is the most sensitive behavioral technique for assessing brainstem integrity.
5. It can be used to assess in the following clinical conditions, effects of cerebral pathology on binaural interaction, effects of brainstem pathology on binaural interaction, effects of cochlear pathology on binaural interaction, and effects of middle ear pathology on binaural interaction.
6. Therefore, MLD can be an effective tool in the audiological test battery and 13 plays an important role in the diagnoses of various hearing disorders.
7. Despite being an effective tool, lack of normative data makes it difficult to give a reliable diagnosis.
8. Hence, it became imperative to establish the normative data which could be used for the clinical population.
9. The present study was designed to develop Compact Disc (CD)-based Masking Level Difference (MLD) test for clinical assessment and to establish a normative data.

10. This study also intended to compare masking level differences for low frequencies i.e. 250 Hz & 500 Hz and high frequencies i.e. 2000 Hz & 4000 Hz stimulation in normal hearing individuals.

METHOD

1. All the procedures used conform to the ethical considerations provided by the declaration of Helsinki (2013).

Participants and Selection Criteria

2. A total number of 100 subjects in the age group of 18 to 35 years with mean age of 20.97 years (male = 21.54 and female = 20.54) respectively were inducted.
3. All the subjects inducted, met the inclusive criteria. Inclusion criteria included, otoscopic examination to rule out an external ear infection with no previous history of hearing loss or any complaint of the problems like ear discharge, otalgia, tinnitus, headaches, vertigo or giddiness, head injury or any other trauma to the brain, exposure to loud sounds, and neurological disorders.
4. All the subjects had hearing thresholds within ≤25 dBHL (ANSI, 2004) from 250 Hz through 8000 Hz in both ears.
5. There was no evidence of middle-ear pathology, no signs of dementia (MMSE > 25, Folstein et al., 1975).
6. The mean thresholds for all the frequencies were less than 15 dBHL with the bone conduction thresholds ≤ 10.
7. Bilateral speech recognition thresholds (SRT) ≤ 25 dBHL (ASHA, 1988) and bilateral speech identification scores (SDS) between 90%-100% for all the subjects.

Material

8. *Hardware*: A laptop (Intel (R) Core (TM) i5-2410M CPU @ 2.30GHz, an x64-based processor and 4.00 GB RAM), portable DVD player (DAPIC-589), an RCAconnector,diagnostic two-channel audiometer (GSI-61, Type-B, Class-I) and TDH-50 headphone mounted in MX41/AR supra-aural cushions were used which met the specifications given by ANSI 3.6 (Jiang, 1998) and calibrated tympanometer GSI-Tympstar Pro version 1.

1. *Software:* Windows 10 Professional (64-bit operating system), AuX (Auditory syntaX) and Windows CD burning softwareswere used.

2. The above-mentioned hardware and software was used for developing the MLD stimulus.

3. *Stimulus Generation:*The Phase-I consisted of signal designing.

4. The stimuli for masking level difference (MLD) were generated through AuX (Auditory syntaX) (Kwon, 2012), a scripting syntax specifically designed to describe auditory signals and processing.

5. The signal was designed on the same lines as given by (Wilson, 2003).

6. The two conditions were taken i.e. S_0N_0 and $S\pi N_0$ for the MLD. For the condition (S_0N_0), both the signal and noise phase were 0^0.

7. For the condition ($S\pi N_0$) the signal phase was 180^0 and noise phase was 0^0 respectively.

8. The signal envelope consists of white noise and tone pulses.

9. Each stimulus composed of low frequencies (250 Hz and 500 Hz) and high frequencies (2 kHz and 4 kHz) each.

10. The masker of 3000 ms wide white noise in duration with 25 ms rise and fall time and the tone pulse is of 300ms in duration with 25 ms rise-fall time for all four frequencies with an inter-stimulus gap of 250 ms being used (as in figure 3a & 3b).

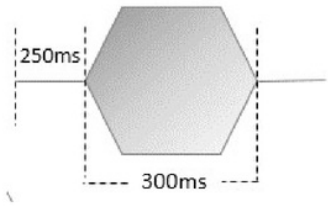

Figure 1: Shows the signal of 300ms in duration with a 25 ms rise/fall time and inter-stimulus gap of 250 ms.

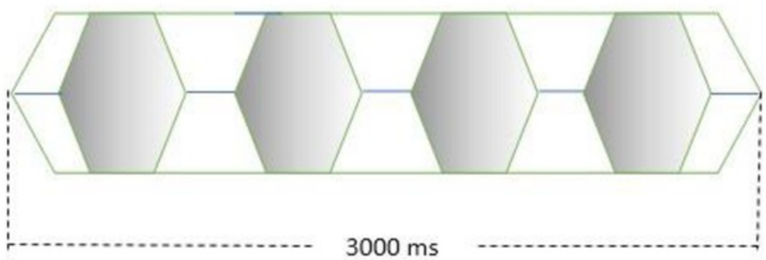

Figure 2: Shows the masker of 3000ms in duration with 25 ms rise/fall time and the signal of 300 ms in duration with a 25 ms rise/fall time and inter-stimulus gap of 250ms.

1. After stimulus generation, each track was written on the CD using Windows CD burning software.
2. A total of 97 tracks written on the CD consisted of 2 practice trials of 500 Hz and 2 kHz each with S_0N_0 and $S_\pi N_0$ conditions having SNR's of +5 dB, a synthetic carrier phrase and a calibrated tone of 1 kHz.
3. The SNR of 1 dB step size taken, ranged from -5 dB to +5 dB for all four frequencies with the S_0N_0 and $S_\pi N_0$ conditions and an inter-stimulus gap of 2 ms given for all the tracks.
4. The order of the stimulus can be seen in the response sheets (as in appendix-II). The duration of the test was nine minutes and fifty one seconds.
5. To record the responses and to calculate the masking level difference (MLD), score sheet and response sheet was made (see appendix - I & II).

6. A sampling frequency of 44.1 kHz with a bit rate of 128 kbps was taken during the stimulus design for the synthetic carrier phrase and the stimulus of S_0N_0 and $S\pi N_0$ conditions.

7. A calibrated diagnostic two-channel audiometer, which was connected to the portable DVD player through RC connector to route the signal through TDH-50 headphones.

8. The phase-II involved administering MLD on the subjects. Prior to MLD test, all the basic audiological evaluation was completed.

9. The basic audiological test included taking history, otoscopic examination, pure tone audiometry, immittance audiometry and speech audiometry i.e. speech recognition thresholds & speech discrimination scores.

1. *Instructions:* The clients were instructed that they will hear a continuous signal in both the ears simultaneously.

2. The signal composed of a masker and the tone and they had to respond to the tone only by raising their hand or by pressing the patient response switch.

3. As with the other auditory measures, testing was done in a sound-treated room that met or exceeded ANSI guidelines for permissible ambient noise for earphone testing (ANSI, 1999).

Procedure

4. Testing was done in a sound-treated room that met or exceeded ANSI guidelines for permissible ambient noise for headphone testing (ANSI, 1999).

5. The signal externally routed through a portable DVD player, was connected through an RCAconnector to the audiometer.

6. The subject was made to sit comfortably in another half of the room.

7. Intensity level for both channels was set at 60 dBSL with decibel steps set to 5 dBHL.

8. Two conditions (S_0N_0 and $S\pi N_0$) were used for the test using low and high frequencies.

9. The responses were obtained and recorded in the MLD response sheet and further thresholds were recorded in the MLD score sheet.

Result

1. The response of each subject was documented in order to analyzeMLD across the four frequencies i.e. 250 Hz, 500 Hz, 2 kHz, and 4 kHz.
2. The collected data was examined and justified, after which classification and tabulation was undertaken.
3. The tabulation data was evaluated with the help of tables.
4. Statistical analysis include descriptive statistics was done to know the mean and standard deviation for male and female participants for two conditions of masking level difference (MLD) i.e. S_0N_0 and $S_\pi N_0$ across the four frequencies i.e. 250 Hz, 500 Hz, 2 kHz, and 4 kHz.
5. One-way ANOVA was done to compare masking level difference (MLD) scores among males and females between four frequencies i.e. 250 Hz, 500 Hz, 2 kHz, and 4 kHz.

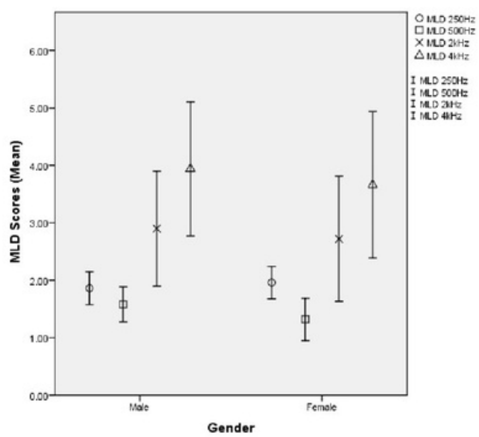

Figure 3. Shows Mean and SD values for males and females for four test frequencies of MLD.

6. Paired sample t-test was done to compare among the MLD thresholds obtained for 250 Hz - 500 Hz as well as 2 kHz - 4 kHz.
7. Paired sample t-test was done to compare the MLD thresholds obtained for low frequency vs high-frequency conditions.

1. The table 1 depicting mean and standard deviation for masking level difference thresholds obtained at all the four test frequencies in both males and females.

Table 1 Shows Mean and SD values for males and females for four test frequencies of MLD.

Gender	N	Mean	Std. Deviation	
MLD 250 Hz	Male	50	1.8600	1.01035
	Female	50	1.9600	0.98892
MLD 500 Hz	Male	50	1.5800	1.07076
	Female	50	1.3200	1.30055
MLD 2000 Hz	Male	50	2.9000	3.51817
	Female	50	2.7200	3.83347
MLD 4000 Hz	Male	50	3.9400	4.10778
	Female	50	3.6600	4.48858

2. One-way ANOVA was done to compare masking level difference scores at 250 Hz, 500 Hz, 2000 Hz, and 4000 Hz between males and females.

3. The results indicated that there was no significant difference between the groups as shown in Table 2, where the value of $p>0.05$.

Table 2 Shows One-way-ANOVA for between groups comparing MLD scores at 250 Hz, 500 Hz, 2 kHz, and 4 kHz

	Df	F	Sig.
MLD 250 Hz	1	.250	.618
MLD 500 Hz	1	1.191	.278
MLD 2000 Hz	1	.060	.807
MLD 4000 Hz	1	.106	.746

4. Paired sample t-test was done to compare between frequencies i.e. MLD thresholds at 250 Hz versus 500Hz and MLD thresholds for 2 kHz versus 4 kHz as shown in Table 3.

5. There was a significant difference for both of the pair of low-frequency MLD (MLD 250 Hz – MLD 500Hz), where $p<0.01$ and for high-frequency MLD (MLD 2 kHz – MLD 4 kHz), where $p<0.05$.

1. Paired sample t-test was done to compare between frequencies i.e. MLD thresholds 250 Hz versus 2 kHz and MLD thresholds and 500 Hz versus to that of 4 kHz. The results are as shown in Table 3.
2. There was a marked significant difference for both the pair of MLD thresholds, where $p<0.01$.
3. Paired sample t-test was done to compare MLD thresholds between frequencies i.e. MLD 250 Hz – MLD 4 kHz and MLD 500Hz – MLD 2 kHz as shown in Table 3.
4. There was a marked significant difference for both the pair, where $p<0.01$.

Table 3 Shows comparison of MLD 250 Hz – MLD 500 Hz and MLD 2 kHz – MLD 4 kHz, MLD 250 Hz - MLD 2 kHz and MLD 500 Hz – MLD 4 kHz & MLD 250Hz – MLD 4kHz and MLD 500Hz – MLD 2kHz (paired sample t-test Statistics)

	t	df	Sig. (2-tailed)
MLD 250 Hz – MLD 500Hz	2.962	99	.004
MLD 2 kHz – MLD 4 kHz	-2.161	99	.033
MLD 250Hz - MLD 2kHz	-2.387	99	.019
MLD 500Hz - MLD 4kHz	-5.541	99	.000
MLD 250Hz – MLD 4kHz	-4.413	99	.000
MLD 500Hz – MLD 2kHz	-3.999	99	.000

Discussion

1. The MLD scores obtained for both the genders (males and females) using four test frequencies i.e. 250 Hz, 500 Hz, 2 kHz and 4 kHz, showed no significant differences as found in the present study.
2. This is supported by Güven&Mutlu (2003)in a similar studywhere MLD scores were not affected by age and gender.
3. The MLD score obtained at 500 Hz frequency was 10.92 dB, but in the present study, it is 1.86 dB (Mean).
4. This difference in the scores of MLD could be due to the variation in the stimuli used as Güven&Mutlu (2003) used narrow band stimuli whereas the present study utilizes white noise as masker.
5. The MLD is largest for low frequencies but large frequencies can also occur for high frequencies when narrow-bandmasker is used (Moore, 2012).
6. Therefore, narrow band noise needs more levels to mask the same tone as compared to white noise which will result in poor signal to noise ratio.
7. This difference in MLD scores is because MLD falls to 2-3 dB for the signal frequencies above about 1.5 kHz for using broadband masker (Moore, 2012).
8. However, it was established in a study done by McPherson, et al., (2011), that MLDs threshold may vary between males and females but there is no significant difference for both the gendersalthough the purpose of their study was to establish a standardized procedure for clinical use in the measurement of the MLD.
9. They evaluated a computer software program, which uses both an adaptive procedure (MLDA) and a Bekesy procedure (MLDB), in the study.

1. They found that [5] both the MLDA and MLDB procedures showed statistically significant sex differences in the masked thresholds used to obtain the MLD, but not for the calculated MLD value.
2. [7] This indicates that although individual threshold values may vary between genders, the actual MLD value is similar and, therefore, normative MLD data does not need to be reported separately for the males and females.
3. It is known [12] that the firing patterns of auditory nerve fibres are phase locked to the stimulus, particularly at low frequencies whereas at high frequencies signal, it is strenuous for the auditory nerve fibres for the phase locking of the stimulus.
4. As low frequency at MSO (Medial Superior Olive) is tuned to a specific ITD(Interaural Time Difference).
5. [3] This neuron responds best at an ITD of zero and less well at progressively greater ITDs.
6. It also responds, when the two sounds are an entire cycle out of phase.
7. A [1] given nerve fibre does not necessarily fire on every cycle of the stimulus but, when firings do occur, they occur at roughly the same phase of the waveform each time.
8. Thus, the time intervals between firings are approximately integer multiples of the period of the stimulating waveform.
9. [4] Large MLDs associated with antiphasic conditions may be related to this phase locking in the neural coding of the stimuli (Green and Henning, 1969).
10. Furthermore, since the degree of phase locking is greatest at low frequencies, and decreases as the frequency becomes higher.
11. Below about 5 kHz frequency in [14] response to a sinusoid, the nerve firings tend to be phase locked, or synchronised, to the evoked waveform on the basilar membrane.
12. [1] Neurones do not fire in a completely regular manner.

1. However, information about the period of the stimulating waveform is carried unambiguously in the temporal pattern of firing of a single neurone.
2. Phase locking does not occur over the whole range of audible frequencies.
3. In most mammals, it becomes progressively less precise for stimulus frequencies above 1 kHz, and it disappears completely at about 4–5 kHz, although the exact upper limit varies somewhat across species (Palmer and Russell, 1986).
4. Phase locking improves in precision with increasing sound level at low levels and then stays roughly constant in precision over a very wide range of sound levels.
5. The phase locking at the MGB to periodicities in the acoustic signal is poor i.e. the phase lock only upto 100 to 200 Hz which is known as entrainment (Musiek and Baran, 1986).
6. Low-frequency entrainment helps in the encoding of the fundamental frequency (F_0) for pitch perception and amplitude modulation coding for spectral information (Phillips & Farmer,1990).
7. Low frequencies are tuned to a specific ITD and neurons responds best at an ITD of zero and high frequencies are less tuned to ITD so they have progressively greater ITDs.
8. Therefore, low frequency can also responds, when the two sounds are an entire cycle out of phase.
9. Fibers with characteristic frequencies below 1500 Hz behave differently with regard to change in filter function with sound intensity than do fibers with characteristic frequencies above 1500 Hz.
10. So, MLD in presence of noise can be detected easily with low frequency sinusoidal tone rather than a high frequency sinusoidal tone.
11. Generally, low frequencies MLDs have been regarded to be the result of the auditory nervous system's ability to operate on the interaural time differences that are generated in the MLD conditions, and the failure to obtain large MLDs at high signal frequencies has

generally been attributed to the auditory system's inability to process time differences above about 1000-1500 Hz.

1. The small MLDs that are observed with high-frequency signals have typically been attributed to the interaural level (intensity) differences that are also available in MLD conditions.
2. However, some experiments have shown that this account has not been precisely correct; MLDs of substantial magnitude can often be obtained at low frequencies even when an interaural level difference is the only binaural cue available for processing (McFadden &Pasanen, 1974).
3. Olsen et al. (1976), they found that MLDs were 8 dB or greater when they compared listening conditions N_0S_0 with $N_0S\pi$ in normal hearing conditions.
4. They also indicated that MLD could be greater than 18 dB. The stimulus used in their experiment was a masking noise of 600 Hz centered at 500 Hz, which was produced by a Bekesy audiometer with 50% duty cycle and a 25 ms rise-fall time.
5. The MLDs for sinusoids can be as large as 14-18 dB from 200-500 Hz and considerably smaller for 2 kHz i.e. 2-3 dB (Harris et al., 1992).
6. Clinical MLD norms established on one type noise should not be used to interpret MLD results obtained using a different type of noise (Harris et al., 1992)

Conclusion

1. The results indicated that there was no significant difference between genders (males and females).
2. However, there was a significant difference for the pair of low-frequency MLD (MLD 250 Hz – MLD 500Hz), high-frequency MLD (MLD 2 kHz – MLD 4 kHz), MLD thresholds 250 Hz - 2 kHz, MLD thresholds 500 Hz - 4 kHz, MLD 250 Hz – MLD 4 kHz and MLD 500 Hz – MLD 2 kHz.
3. This difference was seen because auditory nerve fibres are phase-locked to the stimulus, particularly at low frequencies whereas at high frequencies signal, it is strenuous for the auditory nerve fibres for the phase locking of the stimulus as low frequency at MSO is tuned to a specific ITD.
4. Hence, the tool can be used to analyse MLD in the population although further studies would be required to establish its validity and reliability scores.

Future Directions

1. Masking Level Difference (MLD) is an effective test in identifying lesion in auditory brainstem and above auditory cortical structures.
2. Various stimuli such as pure tones, narrow band noise (NBN), white noise, amplitude-modulated signals etc. are used for identifying the lesion in the auditory brainstem structures. Most of the studies have limitations due to many factors.
3. However, an effect of various stimuli i.e. puretones, narrow band noise, white noise and amplitude-modulated signal, has not been studied much in a single study, in normal as well as in the hearing disorders population.
4. MLD can also be used for measuring the effectiveness of implantable devices such as middle ear implant, cochlear implant, and auditory brainstem implant.
5. So, normative can be determined to increase the utility of MLD clinically.

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