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EFFECT OF AGE AND PHYSICAL EXERCISE ON AMPLITUDE MODULATION DETECTION THRESHOLDS

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ABSTRACT

The present study aimed to investigate the effect of aging on amplitude modulation detection thresholds (MDT) and also to investigate the effect of physical exercise on MDT in older adults. Thirty six individuals were divided into three groups with twelve participants in each group. Group1 consisted of younger adults (YA), group2 consisted older adults who underwent systematic physical exercise program (OA-E) and group3 consisted of older adults (OA) who did not undergo physical exercise. All the participants had normal hearing.MDT was measured at two carrier frequencies (500Hz and 4000Hz) and four modulation frequencies (8Hz, 16Hz, 32Hz and 64Hz). MDT of YA was significantly better than the OA-E and OA suggesting that,despite having normal hearing sensitivity, temporal processing is poor in older adults. Physical exercise had positive effect on MDT at 16Hz, 32Hz and 64Hz modulation frequency for 500Hz carrier frequency indicating that, physical exercise possibly improves the temporal.

KEYWORDS: **Temporal processing, Modulation detection thresholds, Aging, Older adults, Physical exercise**

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INTRODUCTION

Presbycusis is age related hearing loss which is primarily characterized by elevation of pure tone thresholds at high frequencies. [1] Unfortunately, elevated hearing thresholds at high frequencies lead to some of the speech perception difficulties experienced by the older adults [2]. Although, pure-tone thresholds have frequently been used to define auditory handicap, it will not take into account of the speech discrimination abilities at supra-threshold levels. Various researches have shown that older adults have more difficulty in understanding speech compared to younger adults even when they are matched to hearing acuity and for the ability to understand speech in quiet. [3–6] One possible reason for this could be reduced ability to process temporal (time) information. [6,7] Good temporal resolution is necessary for speech perception as it provides valuable information about vowels, consonants and phrase boundaries. [8] Number of studies have shown reduced temporal processing abilities in aging individuals. [6,7,9–14] Temporal resolution can be measured in several ways and one of the commonly used method is temporal modulation transfer function (TMTF). Age related differences are present in TMTF shapes. For older adults, with increasing modulation frequency (MDT), the amplitude modulation detection also increases continuously. This reflects poor identification of “faster envelope fluctuations” due to age-related decline in temporal processing. [15] Takahashi and Bacon[16] measured MDT for amplitude modulated signals in three older adult groups (50, 60, and 70 years) and one younger adult group. The stimuli consisted of a broadband noise as the carrier, which was amplitude modulated at modulation frequencies ranging from 2-1024Hz. Results revealed that, MDT of all the three older adult groups was poorer than younger adult group. Electrophysiological studies also suggest that, age-related decline in temporal processing occurs. Many studies have used mismatch negativity (MMN) and late auditory evoked potential (AEP) to study the sensory encoding of temporal cues. Pekkonen et al. [17] reported, a reduced MMN amplitude in older adults when duration deviance was used. Frequency following responses for amplitude modulation (AM) also revealed weaker AM coding in older adults when compare to younger adults. [18,19] Recently physical exercises are gaining popularity as the tool to offset the effect of aging on hearing. This is because of the better hearing acuity reported in elderly population who underwent regular aerobic exercise program. [20,21] Age related hearing deficit is often viewed as the result of decline in metabolic processing. Due to decline in metabolic processing, blood circulation to the inner ear is reduced, particularly to the cochlea. This reduction in cochlear blood flow may inhibit the oxygen and glucose supply to the cochlea leading to reduced hearing sensitivity. [22] However, the physical exercises improve the blood circulation to the cochlea, which in turn improves the hearing sensitivity. [23] Even though the effect of physical exercises on hearing thresholds has been reported, the effect of physical exercise on supra threshold auditory processing in older population has not been investigated.MDT is one such supra-threshold auditory processing which is found to be affected in older adults. Thus the present study was undertaken to investigate the effect of aging and physical exercise on MDT.

MATERIALS AND METHODS

Thirty six individuals participated in the current study and they were divided into three groups with twelve participants in each group. All the participants of group one were within the age range of 18-25 years. In the subsequent sections, this group will be referred as YA (Young Adults). Participants of group two and group three were within the age range of 56-65 years. Independent t-test revealed no significant difference in age between group two and group three (t_{22}= -1.42, p = 0.57). The participants recruited for the study had normal hearing thresholds of ≤ 25 dBHL at octave frequencies from 250 to 4000 Hz. Individuals with history of any otologic, gross neurological and cognitive impairment were excluded from the study. Through interview it was ascertained that participants of group three did not undergo any form of physical exercise whereas participants of group two underwent a structured physical exercise program regularly. The structured program included muscle stretching exercises for one hour each day. The duration of exercise varied across participants with mean duration of 31.9 months. Group two and group three will be referred as OA-E (Older Adults-Exercise) and OA (Older Adults) respectively in the following sections. In OA and OA-E together, four participants were aged below 60 years. In India, according to Maintenance and Welfare of Parents and Senior citizens Act, individuals above the age of 60 years are considered as “older persons”. However, auditory aging initiates much before 60 years. Hence in the present study these participants were considered as older adults. Similarly, few other studies have also used below 60 years as older adults. [24,25] Informed consent was obtained from all the participants prior to the conduction of the study. Instrumentation: Stimuli for experiment were presented from Acer Aspire one D255 laptop. The output of the laptop was routed through 24-bit Creative sound blaster X Fi USB2 sound card, and the stimuli were presented through TDH-39 head phone with circum-aural PELTER earmuffs. Output of the head phone was calibrated in an AEC100 NBS 9-A 6cc coupler using a Larson-Davis system 824 sound level meter. Signal Processing: To estimate TMTF, modulation detection threshold (MDT) was obtained across 8 Hz, 16 Hz, 32 Hz and 64 Hz modulation rates. TMTF was obtained at 500 Hz and 4000 Hz carrier frequencies. To obtain modulation detection threshold, modulation index was adaptively varied. Both carrier and modulation frequencies were generated at a sampling frequency of 44100 Hz and for the duration of 500 msec. Modulated and unmodulated signals both were ramped with 10 msec cosine onset/offset ramps. Both the carrier frequencies were amplitude modulated at 8 Hz, 16 Hz, 32 Hz, and 64 Hz modulation rates using the formula [26] ;

$$x(t) = 1 - mi \times \left(\frac{1 + \sin(2\pi f_m t)}{2}\right) \times \sin(2\pi f_c t)$$

where, **Error! Reference source not found.**= modulation index whose value ranges between 0 and 1
Error! Reference source not found.= modulation frequency
Error! Reference source not found.= carrier frequency
Further, **Error! Reference source not found.** was converted to decibel scale using the formula;

$$dB = 20\log_{10} m_i$$

PROCEDURE

Participants were made to sit comfortably in a sound treated room. Stimuli for the tasks were presented using the laptop routed through creative sound blaster X Fi USB2 sound card with TDH-39 headphones. For all the tasks sufficient training was provided prior to testing. A response feedback was provided for all the tasks. To estimate MDT, a transformed up down procedure (2-down 1-up) with two alternate forced choice (2AFC) task was used. While obtaining MDT, the target interval consisted of the modulated signal and the non-target interval consisted of unmodulated signal. In all the three tasks, inter stimulus duration between the target and non-target interval was 200 msec. Modulation index was varied adaptively with a ratio step size of 1.1 for MDT at both the carrier frequencies across all modulation rates. In all the three tasks, subjects were asked to identify the target interval. Midpoints of last six reversals from the total eight reversals were geometrically averaged.

RESULTS

Three-way ANOVA with repeated measures was performed to investigate the main effect of carrier frequency, modulation frequency and group, on MDT. Analysis revealed significant difference in MDT between the groups (F (2, 33) = 27.27, p = 0.00). Similarly, carrier frequency also had a significant effect on MDT (F (1, 33) = 83.57, p = 0.00), but no significant effect was shown for modulation frequency on MDT. Significant interaction between carrier frequency and groups was found (F (2, 33) = 24.69, p = 0.00). Since there was a significant interaction between carrier frequency and groups, follow up one way ANOVA was carried out separately at each carrier frequencies and modulation frequencies. One-way ANOVA was performed to investigate the difference in MDT between the groups at 500 Hz carrier frequency for 8 Hz, 16 Hz, 32 Hz and 64 Hz modulation rate. Analysis revealed a significant difference in MDT at 500 Hz carrier across all modulation rates. 'F', 'degrees of freedom' and 'p' values are provided in table 1. Since there was a significant difference in MDT at 500 Hz carrier for all modulation rates, pair wise comparisons between the groups were performed with Tukey's HSD correction. MDT at 8 Hz modulation rate for YA was significantly lower than OA-E (p = 0.00) and OA (p = 0.00). Also, no significant difference between OA-E and OA (p = 0.21) was present. MDT at 16 Hz modulation rate for YA was significantly lower than OA-E (p = 0.00) and OA (p = 0.00). Also, OA-E exhibited significantly lower MDT than OA (p = 0.03). At 32 Hz modulation rate, MDT for YA was significantly lower than OA-E (p = 0.00) and OA (p = 0.00). Also, OA-E exhibited significantly lower MDT than OA (p = 0.00). MDT at 64 Hz modulation rate for YA was significantly lower than OA-E (p = 0.00) and OA (p = 0.00). Also, OA-E exhibited significantly lower MDT than OA (p = 0.00).The mean and standard deviation of MDT at 500 Hz and for all the three groups are represented in figure 1.

Table 1
F-values, degrees of freedom (df) and p values for MDT for 500 Hz and 4000 Hz carrier frequency across all the modulation rates (8 Hz, 16 Hz, 32 Hz and 64 Hz).

Carrier (Hz)	Modulation frequency (Hz)	Df	F (values)	P
500 Hz	8	2, 35	36.78	0.000*
	16	2, 35	26.76	0.000*
	32	2, 35	45.41	0.000*
	64	2, 35	34.85	0.000*
4000 Hz	8	2, 35	3.57	0.039*
	16	2, 35	4.31	0.022*
	32	2, 35	3.05	0.060
	64	2,35	2.46	0.101

***Indicate significance at 0.05 Level.**

Similarly one way ANOVA was also carried out to investigate the difference in MDT among the groups at 4000 Hz carrier for 8 Hz, 16 Hz, 32 Hz and 64 Hz modulation rate. Analysis revealed a significant difference in MDT among the groups at 8 Hz and 16 Hz modulation rate, but no significant difference in MDT for 32 Hz and 64 Hz modulation frequency was present. 'F', 'degrees of freedom' and 'p' values are provided in table 1. Since there was a significant difference in MDT for 8 Hz and 16 Hz modulation rates, pair wise comparisons between the groups were performed with Tukey's HSD correction. MDT at 8 Hz modulation rate for YA was significantly lower than OA (p = 0.03). But, no significant difference between YA and OA-E (p = 0.19) and as well as between OA-E and OA (p = 0.68) was found. MDT at 16 Hz modulation rate for YA was significantly lower than OA (p = 0.02). But, no significant difference between YA and OA-E (p = 0.09) and as well as between OA-E and OA (p = 0.79) was found. The mean and standard deviation of MDT at 500 Hz and at all modulation rates for all the three groups are represented in figure 2

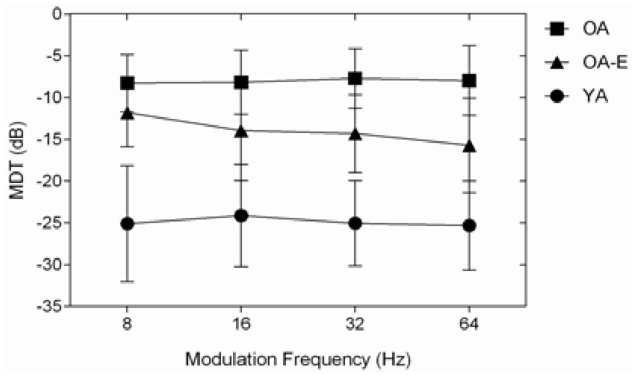

Figure 1
Line graphs depicts the mean values and error bars representing mean±1SD of MDTs for 500Hz carrier at four different modulation rates (8Hz, 16Hz, 32Hz, 64Hz) in all the three groups

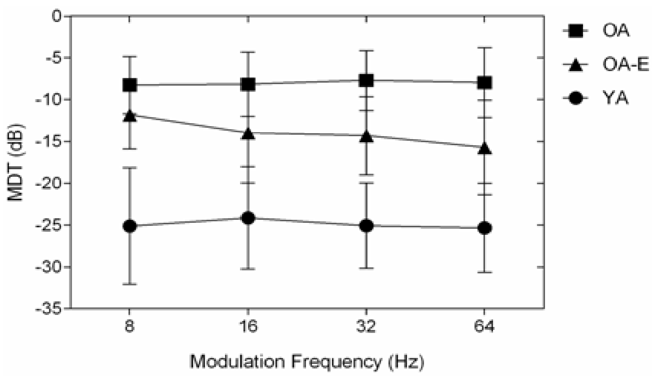

Figure 2
Line graphs depicts the mean values and error bars representing mean±1SD of MDTs for 4000Hz carrier at four different modulation rates (8Hz, 16Hz, 32Hz, 64Hz) in all the three groups.

DISCUSSION

The present study investigated the effect of aging on TMTF by comparing TMTF of older and younger adults. The effect of physical exercises on TMTF in older adults was also assessed. In the current study, MDTs were poorer in older adults than younger adults at both carrier frequencies and the age effect on MDT was larger for the 500 Hz carrier than for the 4000 Hz carrier. The results of the study are consistent with the previous literature. [15] This frequency dependent aging effect could be because of the greater phase locking in lower than higher carrier frequencies. Since, the phase locking ability declines with age, the effect is pronounced in lower frequency carrier than in the higher frequency carrier.[15,18] It can be observed from the figure 2 that, at 4000Hz carrier frequency (bottom panel), as the modulation frequency increases difference in MDT between young adults and older adults decreases. Since, the temporal mechanism is sluggish at higher carrier [27] and modulation frequencies even in young adults the difference in MDT between younger adults and older adults is reduced. Age effect was seen even when additional spectral cues were available along with temporal cues (example: MDT for 64Hz modulation frequency at 500Hz carrier frequency). Physical exercise had positive effect on MDT at 16Hz, 32Hz and 64Hz modulation frequency at 500Hz carrier frequency indicating that, physical exercise possibly improves the temporal coding. Overall results of TMTF reflect that, whenever temporal coding advantage is present, younger adults outperform older adults. But when temporal coding is less efficient younger adults perform similar to older adults or difference in performance between them is less. Evidence for poor temporal coding mainly comes from animal studies. These evidences supported the theory that, aging is associated with slower neural processing [28], prolonged neural refractory times[29,30], increased variability in neural firing [30–32] and inappropriate timing, which lead to poor phase locking there by leading to poor temporal resolution. [33] Positive effect of physical exercise on temporal processing can be attributed to the improved endo-cochlear potentials. It has been reported that decline in metabolic processing is the predominant cause for poor auditory functioning in older adults. [34,35] The Stria vascularis (SV) is responsible for production and maintenance of steady state endo-cochlear potential (EP) for which good oxygenated blood supply is required. Age related reduction in vascular supply [36] leads to loss of EP within the cochlea. However, physical exercises increase the blood supply to the cochlea, there by serving as a protective mechanism against EP decline. There is a positive association between EP and synaptic transmission efficiency. [37] Hence it is reasonable to expect that, physical exercise improve temporal synchrony.

CONCLUSION

The present study investigated the effect of aging on TMTF. Results revealed that there was a significant difference in TMTF between the older and younger adults. The age effect seen was larger for lower carrier frequencies compared to the higher carrier frequencies. Physical exercise had a positive effect on TMTF in older adults. Thus from the current study it can be concluded that, despite having normal hearing sensitivity, temporal processing is poor in older adults. Results of the study suggest that Physical exercise can be used as protective mechanism to offset the age-related deficits in auditory processing to some extent.

CONFLICT OF INTEREST

Conflict of interest declared none.

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