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ORIGINAL ARTICLE

Evaluation of Temporal Processing Abilities in Competing Noise

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Abstract Temporal processing is critical to a wide variety of everyday listening tasks, including speech perception. Although the importance of signal to noise ratio (SNR) is well documented in speech perception experiments, it is less explored in temporal processing experiments. The present study examined the effect of SNR on temporal processing abilities using Gap Detection Threshold (GDT) in children and adults. The study included a total of 45 subjects, where in, 25 children (Group-1) and 20 adults (Group-2) with pure-tone thresholds ranging from 0 to 25 dB HL at frequency range 250–8000 Hz. The GDT was measured at presentation level 50 dBSL. All the measurements were performed in 5 different conditions: 'Quiet', ' + 10 dB SNR', ' + 5 dB SNR', ' + 0 dB SNR' and ' − 5 dB SNR'. Gap Detection Thresholds are significantly higher from + 10 to − 5 dB SNR when compared to quiet condition in young-adults and all sub-groups of children, whereas at + 10 dB SNR, thresholds were not significantly different from quiet condition in young-adults and all sub-groups of children except for sub-group A of children, and were significantly different for all the five conditions. It was revealed that, as the signal to noise ratio (SNR) was decreased from + 10 dB SNR to 0 dB SNR there was a significant increase in Gap Detection Thresholds. There was a significant increase in Gap Detection Thresholds from + 10 dB SNR to − 5 dB SNR in both children and adults. The results also suggest that the performance on temporal processing task in the presence of background noise achieves young-adult like pattern by the age of 10–11 years. Background noise affect temporal processing in both children and young-adults. Background noise impairs temporal processing in children more than the adults, which could be because of poor temporal resolving abilities in children.

Keywords Temporal processing · Signal-to-noise ratio · Gap detection threshold

Introduction

Temporal processing refers to the ability of auditory system to detect acoustic signal in time domain. Temporal processing is crucial in everyday listening situations including speech perception in competing noise [12]. Temporal processing encompasses a wide range of auditory skills including temporal resolution or temporal discrimination, masking, temporal ordering, as well as localization and pitch perception [2]. The most common and reliable way of examining temporal processing is with Gap Detection Tests.

It is generally acknowledged that temporal processing improves considerably over the first several years of life, for example, the age of achievement of adult-like temporal acuity is reported to be between 5 and 6 years of age by few researchers [9, 11] and 9–11 years of age by others [4, 6, 8]. Shivaprakash [15] developed normative data for Gap detection test in children and young adults with normal hearing [15]. The findings suggest that normal hearing individuals start performing like adults on Gap detection test by the age of 6–7 years.

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In everyday listening conditions, there is always some noise present. The adverse effects of noise on hearing are known for centuries. This background noise typically affects Detection tasks, in which, raise in auditory thresholds for tones and speech [7] and Speech perception tasks [5, 13, 18]. Hearing impaired individuals do not complain about understanding speech in quiet environment, but may have some difficulty in noisy environments [19]. Although the importance of signal to noise ratio (SNR) is well documented in speech perception experiments [3, 12, 17], it was less explored in temporal processing experiments. The present study examined the effect of Signal to Noise Ratio on temporal processing abilities using Gap Detection Test in children and adults. We also investigated the differences in temporal processing in children and adults.

Methods

Subjects

The study included a total of 45 subjects, where in, 25 children (Group-1) and 20 adults (Group-2), with pure-tone thresholds ranging from 0 to 25 dB HL at frequency range 250 to 8000 Hz. Group-1 was further divided into Group A (7–7.11Years), Group B (8–8.11 Years), Group C (9–9.11 Years), Group D (10–10.11 Years) and Group E (11–12 Years). Group 2 consisted adults with age ranged 18 to 30 years.

Procedure

The stimuli were presented through a GSI Diagnostic Audiometer (Grason-Stadler Inc.) connected to a computer. The measurements were carried out in sound treated room [1]. The stimuli consist of pairs of pure tones with frequency of 1000 Hz, with intervals /gaps between the two tones. The subject was instructed to gesture whether hearing one or two tones, i.e., whether or not an inter-stimuli gap was noticed. Thus we established the shortest time interval between two pure tones that could be perceived by the subject, that is, to determine the gap detection threshold. The thresholds (GDT) were measured at presentation level 50 dBSL. All the measurements were done on right side and thresholds obtained in 5 different conditions; 'Quiet', ' + 10 dB SNR', ' + 5 dB SNR', '0 dB SNR' and '-5 dB SNR'. White noise was presented ipsilaterally at the respective Signal- to- Noise Ratio (SNR).

Results

Results of repeated measures of ANOVA shown a significant difference in Gap Detection Threshold between both the groups i.e. children and young-adults for all the five conditions (F (1, 43) = 22.906 ($p < 0.001$). It was also shown (Fig. 1) that Gap Detection Threshold was significantly different in all the five conditions for children and young-adults (F (4, 172) = 1152.792 ($p < 0.001$). It was evident from Bonferroni's test that, among all the five conditions Gap Detection Thresholds were significantly different. There was also a significant interaction between groups and conditions (F (4, 172) = 13.964, $p < 0.001$).

The results also showed a significant difference in Gap Detection Threshold of children across the five conditions (F (4, 96) = 614.632 ($P < 0.001$). Similarly in young-adults, significant difference in Gap Detection Threshold across the five conditions was depicted (F (4, 76) = 648.807 ($P < 0.001$). Figure 2 represents the mean differences in Gap Detection Threshold (GDT) of both the groups i.e. children (GDT of sub-groups that constituted children of different ages represented separately) and young-adults for all the five condition i.e. Quiet, + 10 dB SNR, + 5 dB SNR, 0 dB SNR and -5 dB SNR.

The following performance (Figs. 3 and 4) was seen (Mann–Whitney Test) on Gap Detection Test of each subgroup of children versus young-adults for all measurement conditions; Quiet, + 10 dB SNR, + 5 dB SNR, 0 dB SNR and -5 dB SNR. Gap Detection Thresholds of Sub-group A (7–7.11 years) and sub-group B (8–8.11 years) of children was significantly different from young-adults for all the five conditions. Gap Detection Thresholds of sub-group C (9–9.11 years) of children were significantly different from young-adults for four conditions i.e. + 10 dB SNR, + 5 dB SNR, 0 dB SNR and -5 dB SNR and no significant difference for quiet condition. Gap Detection Thresholds of sub-group D (10–10.11 years) and sub-group E (11–12 years) of children were not significantly different from young-adults in any of the measurement conditions. Figure 5 represents that, as the age increases from 7 to

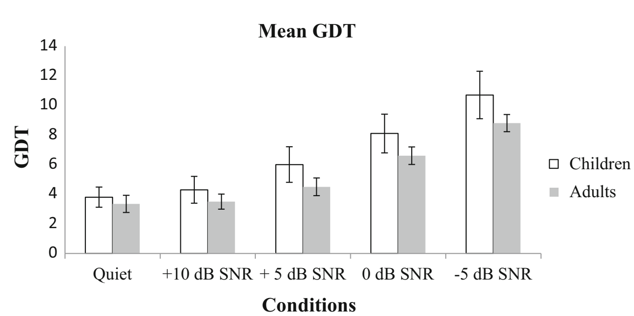

Fig. 1 Illustrate overall mean and standard deviation of Gap Detection Threshold for children and adults in all the five conditions

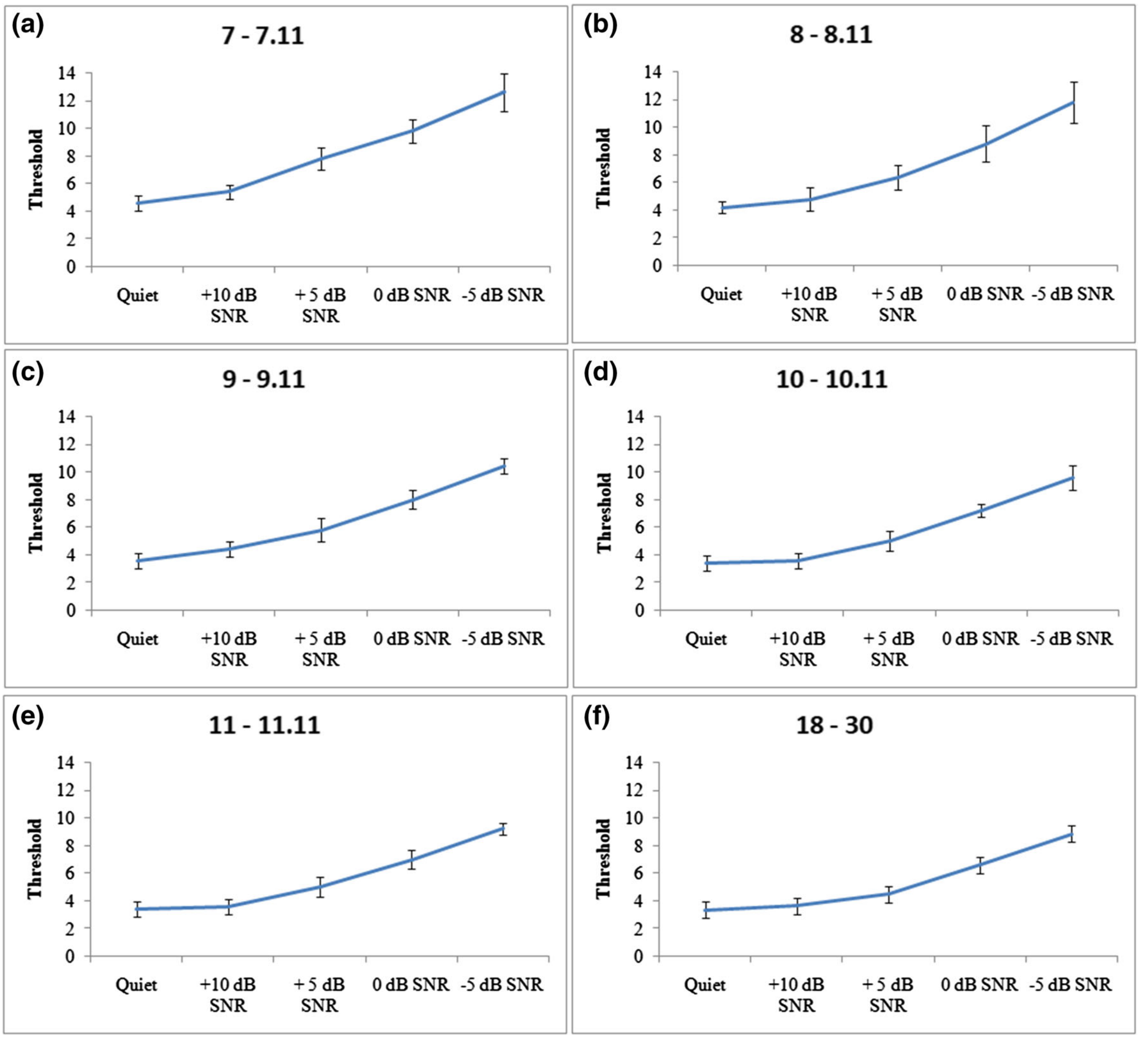

Fig. 2 Charts **a**, **b**, **c**, **d**, **e** and **f** illustrate the Mean and SD of GDTs of all age groups 7–7.11, 8–8.11, 9–9.11, 10–10.11, 11–11.11 and 18–30 years respectively

11 years, the GDTs were coming down and attained adult like performance.

Discussion

Gap Detection Thresholds in Quiet

Overall results showed a significant difference in Gap Detection Thresholds of children and young- adults in 'Quiet' condition. Gap Detection Thresholds of sub-group A and sub-group B of children were significantly higher than young-adults in quiet condition, whereas the Gap Detection Thresholds of sub-group C, sub-group D and sub-group E of children are not significantly different than adults in quiet conditions. The results of the present study suggest that temporal processing in children develop till the age of 8–9 years and children perform equivalently to the young-adults on Gap Detection Test by the age of 9–10 years.

There was a considerable amount of contradiction in literature about the age at which children acquire similar performance of adults in temporal processing tasks. This finding on GDT is contrary to the findings of [9, 11], which suggested that the age of achievement of adult like temporal acuity is between 5 and 6 years. The results of the study also contradict the finding of [15], in which children of age 6–7 years perform like adults on Gap Detection Test. This could be because of the different sample size employed in the present study. The result of this study, however draws support from studies done by [4, 6, 8], where it is suggested that children perform equivalently to adults by the age of 9–11 years.[4, 6, 8].

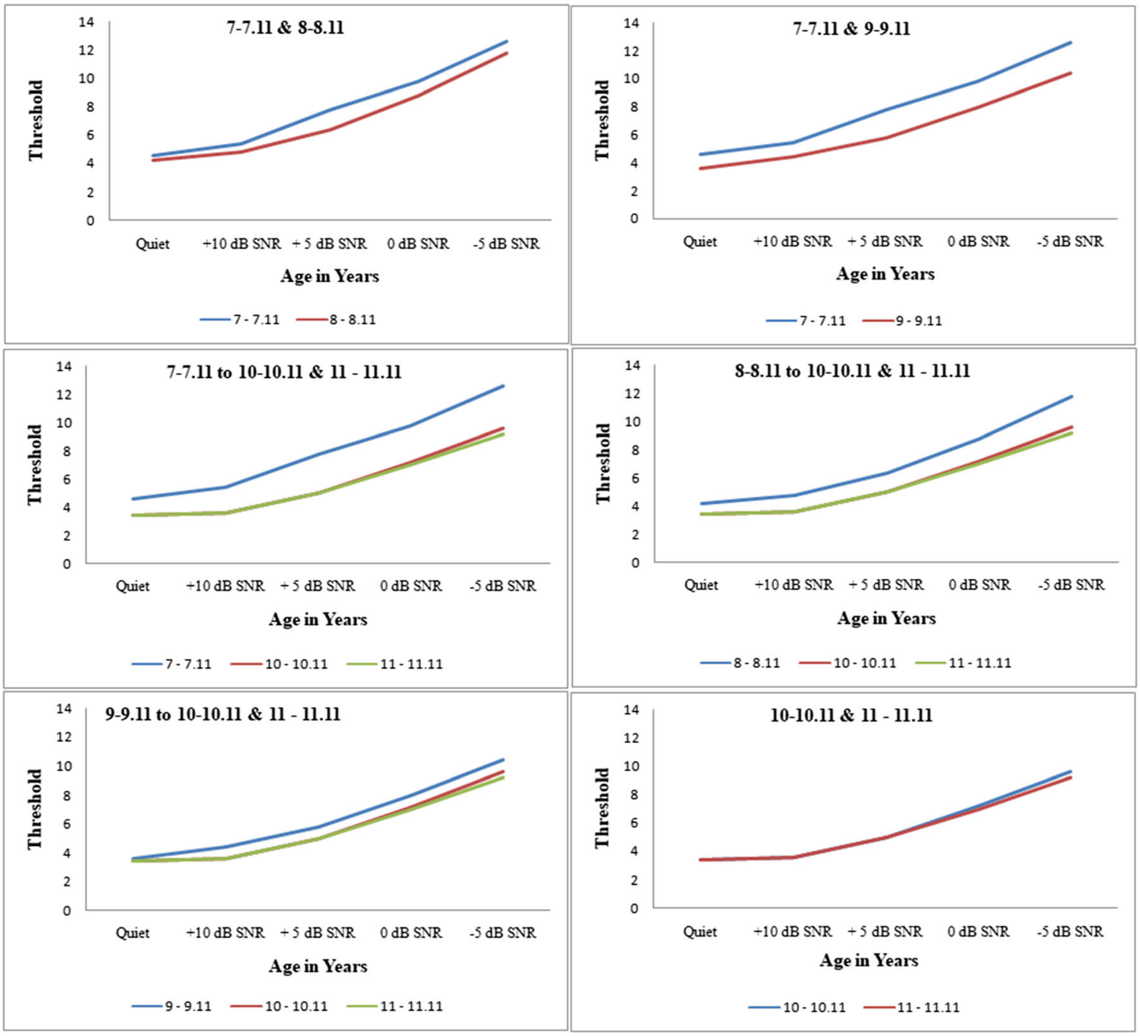

Fig. 3 Charts illustrate mean differences between sub-groups of Children

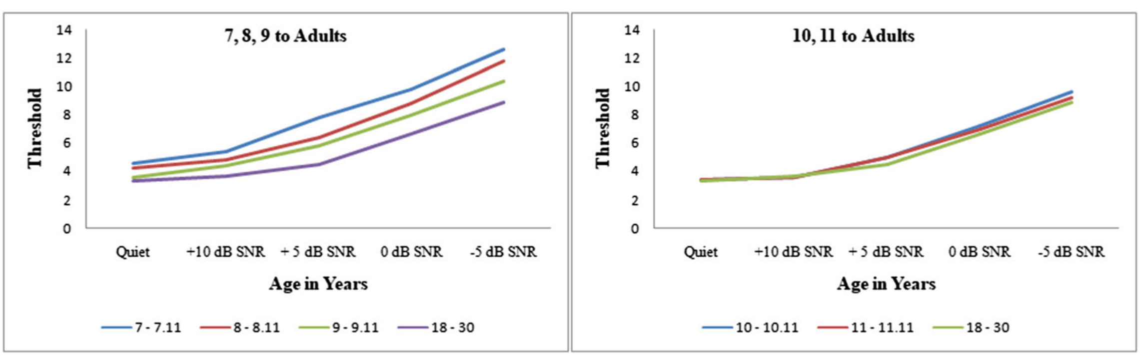

Fig. 4 Charts illustrate Mean Differences between Children and adults

Gap Detection Thresholds in Noise

Adults

Background noise also impairs temporal processing in young-adults. Temporal processing performance deteriorates as the signal to noise ratio (SNR) is decreased. This deterioration in temporal processing task is evident by poorer (increased) Gap Detection Threshold (GDT) with decreasing signal to noise ratio. In general, it is found that GDT increased with the introduction of noise, this can be attributed to the poor temporal resolving power of the

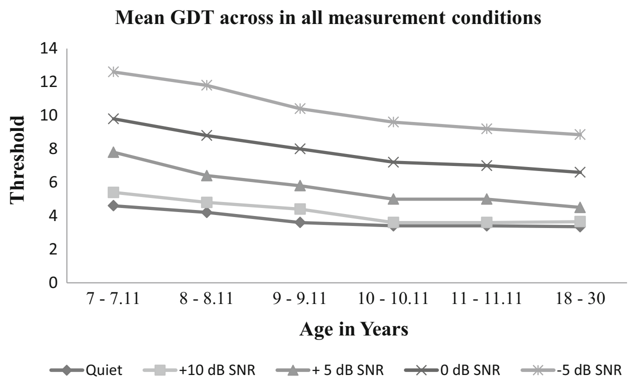

Fig. 5 Illustrate the Gap Detection Thresholds for all the groups in all five measurement conditions

auditory system in the presence of noise. This finding was supported by the studies of [14, 16], where the Gap Detection Thresholds increase with the introduction of background noise.

From the results of the study it is discovered that as the signal to noise ratio (SNR) is decreased from + 10 dB SNR to -5 dB SNR there is a significant increase in Gap Detection Thresholds. This particular result of this study is in accordance with the finding of [14] which suggests that Gap Detection Thresholds increase as signal to noise ratio (SNR) decreases and a SNR better than + 12 dB SNR to + 15 dB SNR do not cause any improvement in the Gap Detection Threshold.

Children

Introduction of background noise raises the Gap Detection Thresholds in children too like adults. This can be due to fact that the presence of noise impairs temporal resolving abilities in children also. There is no quoted study in the literature about the effect of background noise on temporal processing (including Gap Detection Threshold) in children. However, it is evident from the studies on the auditory task performance (including detection tasks and speech perception impairments) in the presence of background noise in children, i.e., noise affects their performance in a variety of auditory tasks [10].

Gap Detection Thresholds are higher for the conditions with the background noise than in quiet and Thresholds increases as signal to noise ratio (SNR) is decreased from + 10 to − 5 dB SNR. However, a significant increase in Gap Detection Threshold was not seen in + 10 dB SNR condition, except for children in sub-group A. From this result it can be suggested that higher SNRs like + 10 dB SNR do not have much effect on the temporal processing task. On the contrary, a poorer signal to noise ratio (SNR) i.e. from + 10 to − 5 dB SNR deteriorates temporal processing in a significant manner. The result of the children in sub-group A can be attributed to their higher sensitivity to noise or poorly developed temporal processing abilities in presence of noise when compared to the other sub-groups of children.

Conclusion

Background noise affects temporal processing in both children and young-adults. Background noise impairs temporal processing in children more than the adults, which could be because of the fact that children are more sensitive to noise, poor temporal resolving abilities in children in presence of noise or poorly developed temporal processing abilities in children as compared to young-adults.

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