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RESEARCH

EFFECT OF AGING ON TEMPORAL RESOLUTION

Abstract

Introduction: The aim of the present study was to evaluate the changes in temporal resolution with aging and the effects of these age-related changes on speech recognition performance.

Materials and Method: 30 young adults with normal-hearing (aged 18 to 30 years) and 25 elderly adults with normal-hearing (aged 60 to 80 years), a total of 55 participants, were included in the study. For each subject, Gaps in Noise Test, Acceptable Noise Level test and Speech Recognition Tests were carried out. Results: No significant difference was observed between the groups in terms of Most Comfortable Level, Background Noise Level and Acceptable Noise Level while there were significant differences in terms of Gaps in Noise threshold, Total Percentage Score and Speech Recognition Scores (p=0.0001). The elderly group had a significantly higher Gaps in Noise threshold and lower Total Percentage Score compared to the younger group. Also, the mean score of speech recognition in the elderly group under all conditions was significantly lower than the younger group (p=0.0001).

Conclusion: The present study showed that temporal resolution decreases with aging and that this reduction in temporal resolution is only one of the underlying reasons of speech recognition difficulties in elderly people and it is concluded that the gaps-in-noise test is a fast and appropriate test for assessing temporal resolution in both young and elderly individuals.

Key Words: Aging; Auditory perception; Speech perception; Time perception

ARAŞTIRMA

YAŞLANMANIN TEMPORAL ÇÖZÜNÜRLÜK ÜZERİNDEKİ ETKİSİ

Öz

Giriş: Bu çalışmada yaşlanmayla birlikte temporal çözünürlükte meydana gelen değişiklikler ve bu değişikliklerin konuşmayı ayırt etme performansı üzerindeki etkilerini değerlendirmek amaçlanmıştır.

Gereç ve Yöntem: Çalışmaya normal işiten 18-30 yaşları arası 30 genç yetişkin ve 60-80 yaşları arası 25 yaşlı yetişkin olmak üzere toplam 55 katılımcı dahil edilmiş, her birine Gürültüde Boşluk Tanıma Testi, Kabul Edilebilir Gürültü Seviyesi Testi ve Konuşma Testleri uygulanmıştır.

Bulgular: Gruplar arasında En Rahat Dinleme Seviyesi, Arka Plan Gürültü Seviyesi ve Kabul Edilebilir Gürültü Seviyesi bakımından anlamlı fark elde edilmezken; Gürültüde Boşluk Tanıma eşiği, Doğru Boşluk Tanıma oranı ve konuşmayı ayırt etme puanları bakımından anlamlı farklar elde edilmiştir (p=0.0001). Yaşlı grupta Gürültüde Boşluk Tanıma eşiği ortalaması genç gruba göre yüksek, Doğru Boşluk Tanıma oranı ortalaması ise istatistiksel olarak düşük elde edilmiştir (p=0.0001). Tüm dinleme koşullarında konuşmayı ayırt etme puanı ortalamaları yaşlı grupta genç gruba göre istatistiksel olarak düşük elde edilmiştir (p=0.0001).

Sonuç: Çalışma sonunda yaşlanma ile beraber işitsel temporal çözünürlüğün azaldığı, bu azalmaların yaşlılardaki konuşmayı ayırt etme güçlüklerinin altında yatan nedenlerden sadece biri olduğu ve gürültüde boşluk tanıma testinin genç ve yaşlı bireylerde temporal çözünürlüğü değerlendirilmek üzere kullanılabilir hızlı ve uygun bir test olduğu sonucuna varılmıştır.

Anahtar Sözcükler: Yaşlanma; İşitsel algı; Konuşma algısı; Zaman algısı

INTRODUCTION

As adults age, some anatomical and physiological deteriorations occur within the auditory system. Age-related reductions in pure tone hearing sensitivity are the most common sensory deficit in the elderly (1,2). Many studies have reported that hearing thresholds decline with age, predominantly in the high frequencies (3,4). Such decline might have some major adverse effects upon communication, particularly in noisy and reverberant listening situations. Previous studies have suggested that older listeners are associated with poorer performance in speech understanding tasks than young listeners and findings from these studies suggested that age-related declines in hearing sensitivity are the primary cause of discrimination problems in older listeners (5,6). On the other hand, Vermeire et al. suggested that speech understanding correlates more with age than with hearing (7). Although similar studies (8,9) report that speech recognition by older subjects is worse than that of younger subjects by an even greater margin than expected considering the degree of hearing loss, a finding partially supported by the findings of Vermeire et al., there is still no consensus with regards to the effects of age-related factors upon speech discrimination. Age-related central processing changes have also been attributed to speech understanding difficulties in older listeners. To understand speech, a listener must be able to resolve specific temporal cues of the speech sound; therefore, temporal resolution is thought to be very important for the accurate understanding of speech. While there have been many studies reporting that temporal resolution declines with age (10,11) other studies suggest that this decline does not correlate with age (7,12). Consequently, there is significant confusion relating to the effects of age upon temporal resolution ability. Therefore, in the present study we assessed temporal resolution, and carry out a number of investigations in respect to speech recognition, age, and temporal resolution. First, The Gaps in Noise Test (GIN) was used to determine and compare temporal resolution performance between young and elderly subjects. Next, it was investigated to what extent speech recognition performance changed in young and elderly individuals at various signal-to-noise ratios and whether temporal resolution ability had an effect upon speech recognition performance. It was also evaluated the degree of correlation between aging and both temporal resolution and speech recognition performance in all subjects. Finally, it was investigated whether the Acceptable Noise Level (ANL) is effective in speech recognition performance in noise.

MATERIALS AND METHOD

30 Thirty young adults aged 18 to 30 years (female: 13; male: 17; mean age 25.16 years, standard deviation ±3.25 years) and 25 elderly adults aged 60 to 80 years (female:14; male:11; mean age: 68.04 years±5.55 years), a total of 55 participants, were included in the study. All participants had normal hearing defined as pure tone thresholds≤25 dB HL at 500, 1000 Hz and≤35 hearing dB HL at 2000 and 4000 Hz. Considering the pure tone averages of 500, 1000, 2000, and 4000 Hz in the best hearing ears of the participants, the pure tone mean of the four frequencies were calculated as 7.62±4.80 dB HL in the younger group and 13.26±8.08 dB HL in the elderly group. Additional criteria for subject selection included normal middle-ear function as determined by acoustic immittance testing and the lack of any known otological, neurological, cognitive, or learning deficits.

The study was done with the approval of Marmara University Health Sciences Institute Clinical Studies Ethics Committee (30/05/2017- 26) and informed consent was obtained from all participants.

Gaps in Noise (GIN), Acceptable Noise Level (ANL) and speech tests were administered to each participant. All tests were performed in sound-treated booths with an ambient noise level, measured by a sound level meter, below 30 dB (A) SPL. The subjects were tested while seated in a comfortable armchair, at 0□ azimuth and one meter away from loudspeaker. All test stimuli were calibrated with a sound level meter by taking a 1000 Hz probe tone as a reference in the free field.

Monosyllabic Word lists that were used for speech recognition test and the speech samples that were used for ANL test were recorded in a professional audio recording studio. Waveform Audio File Format (Wav) was used as the recording and playback format. All speech samples were recorded by a female talker in a 2.5x3x2.5 meter room which was treated acoustically. The carrier phrase was used before the each speech recognition test word. While recording, the microphone was positioned at a distance of 15 centimeters from the mouth of the speaker and at an angle of 45 degrees. Post-recording normalization was performed for each part.

Procedures

a. GIN Test: There are four different tests lists that were developed to be used in the GIN test. The lists contain 60 gaps which are 2, 3, 4, 5, 6, 8, 10, 12, 15 and 20 msec in duration and each is put in order six times and randomly. The number of these gaps embedded within white noise segments of 6 msec varied between 0-3 and the interstimulus interval (segments) is 5 secs. The GIN stimuli which were recorded on a compact disc played through a calibrated audiometer and presented through a loudspeaker at a level of 60 dB SPL. The lists, selected at random, were administered each subject. All subjects were given practice items before the test to ensure the task was understood. They were instructed to press the response button in their hands as soon as they heard any small gap in noise. If the response button was pressed during the gap, it was counted as positive. If the button was not pressed when a gap occurred, it was counted as an error. If the button was pressed when no gap occurred, it was counted as false positive. At the end of the test, the GIN threshold and Total Percentage Score (TPS) were determined (13).

b. ANL Test: Acceptable Noise Level (ANL) is an adaptive measure, to quantify listeners' willingness to listen to speech in the presence of a background noise. Fundamental aspect of this measure is that subjects can self-select their acceptable level of background noise. ANL was determined using recorded speech sample as the primary stimulus and speech noise as the competing background noise. For the ANL procedure, the subjects were given two handheld buttons to adjust the volume up or down in 2 dB steps. First, subjects were instructed to adjust the intensity level of the speech sample to their most comfortable listening level. Next, background noise was added and the subjects were instructed to adjust its level to the highest level where they could easily understand the speech without becoming tense or tired. This level is called the background noise level (BNL). Finally, the ANL was calculated as the difference between the MCL and BNL.

c. Speech Tests: Phonemically balanced Turkish monosyllabic word recognition lists for adults, which were developed as 6 different sets of 25 words, were used to evaluate speech recognition performance (14). Speech Recognition Scores (SRS) were administered in three different conditions and a different word list was used for each condition to avoid the adaptation. Test conditions were (1) Signal at 60 dB SPL, no noise (S60-N0), (2) Signal at 60 dB SPL, speech noise at 60 dB SPL (S60- N60), and (3) Signal at MCL, speech noise at BNL (SMCL-NBNL), respectively.

Statistical Methods

Statistical analyses were performed using the SPSS software version 20 (Chicago, IL, USA). The variables were investigated using visual (histograms, probability plots) and analytical method (Kolmogorov-Simirnov) to determine whether or not they are normally disturbed. Descriptive analyses were presented using means and standard deviations for normally distributed variables.

Statistical analysis was conducted in four parts. First, independent samples t test was used to test the significance of the differences between the groups. Second, paired-samples t test was used to test the significance of the difference between three dependent variables in each group. Third, Pearson's Correlation Coefficients was used to examine the relationship between SRS and three different variables (ANL, GIN thresholds and TPS) for both young and elderly groups. Fourth, effect of age on SRS, GIN threshold, TPS and ANL was also analyzed with correlation coefficient for all subjects. A p value of <0.01 was accepted as the level of significance for all statistical analysis.

RESULTS

GIN Test

The mean GIN threshold was 6.20 msec in the elderly group, compared to 2.86 msec in the younger group. This difference was statistically significant (Table 1). TPS was significantly higher in the younger group (92.7%) compared to the elderly group (76.1%, Table 1). In both groups, GIN threshold and TPS were observed to show a strong negative correlation (r = -0.865).

Speech Test

There was a significant difference in terms of SRS between the two groups for all listening conditions. The mean values for both groups are presented in Table 1. In the young group, the SRS obtained in three different listening conditions were observed to show statistically significant differences with from each other (Table 2). In the elderly group, a significant difference was found between SRS obtained in quiet conditions and in both noise conditions. However, there was no significant difference between SRS obtained in both noise conditions (Table 2).

ANL Test

We did not identify any statistically significant differences in terms of MCL, BNL and ANL values across the groups (Table 1).

The Relationship between GIN Scores and SRS

In the young group, there was no significant correlation between GIN scores and SRS obtained in any of the three listening conditions (Table 3).

In the elderly group, no significant correlation was detected between GIN results and SRS obtained in quiet conditions. Ho wever, a weak negative correlation was found between SRS obtained in both noise conditions and GIN threshold, and a weak positive correlation with TPS (Table 3).

The Relationship between ANL and SRS

In the young group, there was a weak correlation between SRS obtained in condition in which speech was presented only as MCL and noise was presented as BNL. No significant correlation was found between ANL scores and the SRS obtained for other listening conditions (Table 3). In the elderly group, there was no significant correlation between ANL and the SRS obtained for all three listening conditions (Table 3).

The Effect of Age upon Variables

In the study, it was also examined whether there was an age effect on speech recognition performance, temporal resolution performance and ANL by using correlation coefficients, including both groups between the ages of 18-80 years.

Speech tests: A weak negative correlation was found between age and SRS obtained in quiet condition. However, a moderate negative correlation was found between age and SRS obtained in both noise conditions (Table 4).

GIN test: A moderate positive correlation was found between age and GIN threshold, and a moderate negative correlation between age and TPS (Table 4).

ANL test: No significant correlation was found between age and ANL (Table 4).

Table 1. Comparison of mean values for SRS, MCL, BNL, ANL, GIN Threshold and TPS between young and elderly groups.

	Group	N	Mean	Std. Dev.	Mean Dif.	p	t
S60–N0 SRS (%)	Young Elderly	30 25	98.13 95.20	2.92 4.61	2.93	0.006*	2.86
S60-N60 SRS (%)	Young Elderly	30 25	88.46 78.88	5.79 11.74	9.58	0.001*	3.72
SMCL-NBNL SRS (%)	Young Elderly	30 25	93.06 82.24	7.92 10.07	10.82	0.0001*	4.36
MCL (dB HL)	Young Elderly	30 25	61.96 61.68	4.21 4.42	0.28	0.807	0.24
BNL (dB HL)	Young Elderly	30 25	61.3 59.44	4.99 4.77	1.86	0.166	1.40
ANL (dB HL)	Young Elderly	30 25	0.7 2.24	3.06 2.65	-1.54	0.054	-1.97
GIN Threshold (msec)	Young Elderly	30 25	2.86 6.20	1.16 3.14	-3.34	0.0001*	-4.93
TPS (%)	Young Elderly	30 25	92.7 76.12	6.25 13.61	16.58	0.0001*	5.61

Table 2. Differences of SRS obtained from three different listening conditions in the young and elderly groups.

		N	Mean	Std. Dev.	Sig (2-tailed)
Young Group	**S60-N0 S60-N60**	30 30	98.13 88.46	2.92 5.79	0.000*
	S60-N0 SMCL-NBNL	30 30	98.13 93.06	2.92 7.92	0.005*
	S60-N60 SMCL-NBNL	30 30	88.46 93.06	5.79 7.92	0.008*
Elderly Group	**S60-N0 S60-N60**	25 25	95.20 78.88	4.61 11.74	0.000*
	S60-N0 SMCL-NBNL	25 25	95.20 82.24	4.61 10.07	0.000*
	S60-N60 SMCL-NBNL	25 25	78.88 82.24	11.74 10.07	0.059*

S60-N0:Signal at 60 dB SPL, no noise; S60- N60:Signal at 60 dB SPL; noise at 60 dB SPL SMCL-NBNL: Signal at MCL, noise at BNL

Table 3. Relationship between ANL, GIN Threshold and TPS with SRS obtained from three different listening conditions in the young and elderly groups.

			ANL	GIN Threshold	TPS
Young Group	**S60-N0 SRS**	R Sig.(2-tailed) N	-0.01 0.92 30	0.12 0.50 30	-0.04 0.80 30
	60-N60 SRS	R Sig.(2-tailed) N	-0.02 0.92 30	0.01 0.96 30	0.05 0.77 30
	SMCL-NBNL SRS	R Sig.(2-tailed) N	0.45* 0.01 30	0.09 0.63 30	-0.23 0.20 30
Elderly Group	**S60-N0 SRS**	R Sig.(2-tailed) N	-0.13 0.52 25	-0.18 0.38 25	0.35 0.08 25
	S60-N60 SRS	R Sig.(2-tailed) N	-0.32 0.10 25	-0.42* 0.04 25	0.42* 0.03 25
	SMCL-NBNL SRS	R Sig.(2-tailed) N	0.16 0.44 25	-0.36* 0.08 25	0.30* 0.13 25

S60-N0: Signal at 60 dB SPL, No noise; S60- N60: Signal at 60 dB SPL; Noise at 60 dB SPL SMCL-NBNL: Signal at MCL, Noise at BNL

Table 4. Effect of age on variables.

		S60-N0	S60-N60	SMCL - NBNL	ANL	GIN Threshold	TPS
AGE	r	-0.358*	-0.502*	-0.520*	0.300	0.636*	-0.670*
	Sig. (2-tailed)	0.003	0.000	0.000	0.012	0.000	0.000
	N	55	55	55	55	55	55

*Correlation is significant at the 0.01 level (1-tailed).

S60-N0: Signal at 60 dB SPL, No noise; S60- N60: Signal at 60 dB SPL; Noise at 60 dB SPL SMCL-NBNL: Signal at MCL, Noise at BNL

DISCUSSION

The temporal resolution which provides a measure of information about vowels, consonants, syllables and phrase boundaries, is an important function of the central auditory system (15). This auditory function, which takes place through multiple ascending and descending tracts between the cerebral cortex, thalamus, and brainstem nuclei, is accomplished by the accurate and rapid decomposition of auditory information which causes neural activity in the subcortical and cortical areas. When the ability of the auditory system to perceive and process this information deteriorates for any reason, the content information and intelligibility of speech is also deteriorated. In the literature, there are numerous electrophysiological, as well as behavioral studies, stating that the gap detection threshold increases with age. This condition, which is not associated with peripheral injury, is related with the deterioration of temporal resolution with aging (16) and the speed of temporal processing of the elderly in both active and passive listening conditions is suggested to be lower than that of younger subjects, with this reduction being even more evident in complex tasks (17). In our present study, our results were consistent with the literature, and gap detection performance in our elderly group was observed to decrease by approximately two-fold compared to the younger group and continued to decrease with increasing age.

Since it is known that the results obtained may vary depending upon stimulus parameter and stimulus type, broadband stimuli seem to be preferred usually because they are known to cause less variability in gap detection measurements (18). However, in case of a situation when frequency specific information is needed, tonal or various band limited noise stimuli are often used. Since individuals with normal hearing were included in our study, it was considered that spectral information could be neglected. Therefore, the GIN test, including broadband noise stimuli, was used. In addition, assuming that there is no difference between the ears (18, 19); binaural application was performed for the GIN test in order to better reflect the difficulty of discrimination in daily conversation as in the speech tests. As a result of this test, binaural GIN threshold was found to be 2.86 msec in the younger normal-hearing adults and 6.26 msec in the elderly adults. The other studies in the literature using the GIN test, GIN threshold was observed to vary from 3.9 to 5.61 msec in young adults with normal-hearing (7,18,20,21), and from 5.21 to 9 msec in elderly adults with normal-hearing (7,18,20). According to this, the mean GIN thresholds obtained from the young group in our study seem to be lower than those reported previously in the literature while our mean values for the elderly group are quite similar to those in the literature. The fact that the GIN thresholds obtained in the younger group were smaller than those in the literature can be explained by the age ranges accepted for the "young" group are not identical for every study and by the advantages provided by binaural listening. The consistency of our results for the elderly group when compared to the literature was attributed to using a more common definition for elderly people, and age-related reduced binaural processing ability. In order to elucidate this issue, future research should examine the results of monaural and binaural GIN tests across different age groups.

The results obtained in our study, as well as in many previous studies reported in the literature using different gap recognition parameters, clearly show the adverse effect of age upon gap detection performance. These findings, which are the consequence of decline and deterioration in temporal resolution ability, are considered to arise from an age-related decline in neural fiber numbers and related subcortical neural unit and synchronization dysfunction in the neural fibers creating stimulus response patterns (22,23). These deteriorations, which make difficult to detect and understand the fast components of speech, are suggested to be the primary cause of discrimination problems in the elderly (10). However, the presence of many other factors, including peripheral, central, and cognitive processes, which have an impact upon speech perception, make difficult to assess the effect of temporal resolution on discrimination problem alone. Since the contribution of these factors, which have many complex and diverse connections with each other, on listening and communication functions, varies among individuals, the results in the literature are inconsistent with each other. Although the findings indicating that temporal decline begin in the early periods and that deteriorations in speech perception associated with these declines are dominant, auditory temporal processing measurements could not be proven to be a strong indicator to reflect speech recognition performance in elderly individuals (9). In our study, no strong correlation was identified between temporal resolution and speech recognition performance. As a result of the speech recognition tests conducted at three different listening conditions, the scores of both groups obtained in noisy conditions were lower than those obtained in quiet conditions. These findings show that noise is the most important variable on recognition performance. Comparing group performances, the decline in the elderly group was found to be higher than that of the younger group. The more prominent effect of noise upon elderly people can be explained by age-related changes in the efferent system.

In order to investigate the effect of self-determination for the signal-to-noise ratio on speech recognition performance in noise, the assessment was carried out under conditions in which speech was presented as MCL and noise was presented as BNL; no significant difference was observed between the SNRs preferred by either of our test groups. Comparing the scores obtained in two different noise conditions, some improvement was observed to occur in speech recognition scores when individuals determined the signal-to-noise ratio themselves; this improvement was significant in the young group but not in the elderly group. These findings indicated that elderly people have more difficulty in speech perception in noisy conditions and require more SNR. Furthermore, ANL did not correlate with speech recognition performance in noise or with age. In the literature, similar to our study, ANL was not observed to be associated with age (24) or speech recognition performance in noisy conditions (25). The fact that the underlying mechanism for these observations has yet to be elucidated yet, suggests that the studies on the ANL test should continue.

Examining the reduction in gap detection performance of the elderly group in relation to the recognition scores at various signal-to-noise ratios, the gap detection performance was observed to show a weak positive correlation with the scores obtained in noise but not with the scores obtained in quiet conditions. These results, which are consistent with the literature, appear to suggest that the declines in temporal resolution with age have an impact upon speech perception more significantly in noise, but not in quiet. When the relationship between age and speech recognition scores was examined, a negative moderate correlation was found in noise conditions, whereas a weak negative correlation was found in the quite condition. These findings suggest that speech recognition performance is decreased with age, especially in noisy situations.

In conclusion, our study showed that temporal resolution decreased significantly with age, and that these declines correlated with speech recognition scores in noisy conditions but not in quiet conditions. This situation reveals that elderly people have more difficulty in understanding speech in noisy and reverberant environments. On the other hand, the GIN test that we used to assess temporal resolution was highly advantageous since it was quickly applicable, reliable, and relatively simple, compared to the other tests in which using different stimuli were used in the literature. The GIN test was considered to represent a suitable test for routine audiological test batteries to assess temporal resolution in patients admitted to clinics complaining of comprehension difficulty despite normal peripheral hearing.

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