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Effects of the Target Talker Gender and the Number of Competing Talkers on Acceptable Noise Level (ANL) of Korean Normal-Hearing Adults

Jin-Bae Shin and Jae Hee Lee

Department of Audiology, Hallym University of Graduate Studies, Seoul, Korea

국문초록

본 연구에서는 한국건청인의 수용소음레벨을 측정하고 이에 주요한 영향을 미치는 변수를 확인하고자 하였다. 실험측정변수로는 목표화자성별과 배경화자수를 조절하여 두 변수가 한국건청인의 수용가능한 소음레벨(acceptable noise level, ANL)에 미치는 영향을 알아보았다. 본 연구의 청취대상자는 건청성인 20명(남: 9, 여: 11, 평균연령: 26세)이었다. 한국어 ANL 측정을 위해 한국표준어를 사용하는 성인 6명(남: 3, 여: 3)에 의해 목표어음을 녹음하여 목표화자성별의 영향을 확인하였다. ANL 배경어음은 한국표준어를 사용하는 성인 8명(남: 4, 여: 4)이 신문, 잡지를 약 5분간 읽고 녹음하였다. 녹음된 배경어음의 평균 RMS (root mean squared) 강도를 조절한 후 mixing 작업을 통해 다섯 가지 종류의 배경어음(1-male, 1-female, 2-, 4-, 8-talker maskers)을 생성하였다. 모든 ANL 측정방법은 기존 ANL 측정방법(Nabelek et al., 1991)에 기초하였다. 실험결과 목표화자의 성별에 따라 ANL 결과는 유의미한 차이를 보이지 않아, 목표화자가 남자이든 여자이든 ANL에 큰 영향을 주지 않음을 확인하였다. 그러나 배경화자수가 8명에서 1명으로 수가 적어질수록 ANL이 유의하게 높아졌다. ANL 결과가 높을수록 청자가 더 적은 소음을 허용했음을 의미하므로, 배경화자수가 8명에서 1명으로 감소될 경우 배경어음의 의미가 보다 잘 전달되어 의미적 차폐(informational masking)가 발생하여 적은 소음을 수용할 수 있었던 것이다. 한국, 미국 건청인의 ANL을 비교한 결과 ANL 범위는 비슷하나 대체적으로 한국건청인의 ANL값이 비교적 낮은 편이었다. 향후 다양한 한자 한다.

중심 단어 : 목표화자성별 · 배경화자수 · 수용소음레벨.

INTRODUCTION

It is well known that background sounds deteriorate an individual's ability to perform listening tasks in daily listening situations. This may be applied to everyone regardless of hearing status since listening in background noise appears to require a high degree of perceived effort.[13] However, an amount of annoyance produced by noise may vary depending on the type or the number of background noise, the intensity ratio between target-to-masker noise, and the individual differences.

Acceptable noise level (ANL) is one of the useful measures that determine the maximum acceptable noise level of listeners while following a target story.[17] Unlike traditional speech audiometry that usually estimates speech-understanding ability in noise, for the ANL measurement, listeners should self-select the maximum noise level that they are willing to accept while listening to target speech at a comfortable level. In other words, if someone is annoyed by noise greater than other people are, the person's maximum ANL would be higher compared to others.

Regardless whether hearing-impaired listeners use hearing aids or not, the listeners who have similar hearing loss often suffer from the background noise, and the amount of disturbance caused by noise is not the same. Considering this, ANL measure has clinical implication since this measurement directly tests each individual's maximum acceptable noise level while listening to the target speech at conversational level, which commonly occurs in daily life.

The ANL values are obtained from various population groups. An earlier study[9] have found that the persons who

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Corresponding Author: Jae Hee Lee, Department of Audiology, Hallym University of Graduate Studies, 906-18 Daechi-dong, Gangnam-gu, Seoul 135-841, Korea
Tel: +82-02-3453-9333 · 7459, Fax: +82-02-3453-6618 · E-mail: leejaehee@hallym.ac.kr

inclined to accept more noise had more possibilities to be successful hearing-aid users. On the other hand, listeners who tended to less accept the noise were less likely to show a greater satisfaction with hearing aids due to a greater amount of annoyance from noise. Full-time hearing aid users accepted more noise compared to either part-time hearing aid users or non-users. Interestingly, SPIN (speech perception in noise)[3] test score alone does not predict the benefit from hearing aids whereas SPIN score plus ANL are more effective to identify benefit from hearing aids. Therefore, the authors recommended the use of SPIN and ANL together to predict a successful use of hearing aids.[16] In the study of Freyaldenhoven et al., forty listeners with binaural amplification showed significant directional hearing aid benefit on ANL, as well as masked speech reception threshold (SRT), and their ANLs and masked SRTs were significantly correlated.[7] The ANL and speech recognition performance in noise were strongly related to the self-perceived communication ability of cochlear implant (CI) users.[4] This suggests that ANL can be considered to reflect the degree of handicap that CI listeners would have in their lives. The ANL also appears to be more correlated with central auditory processing mechanisms rather than with peripheral auditory system.[11][12][21]

Other research has shown that ANL is not significantly influenced by individual factors such as listener's hearing status, age, gender.[17][19] Similar ANL values were also found between bilingual Korean listeners who use both English and Korean and monolingual English listeners.[22] However, ANLs significantly depend on the presentation level of target speech.[6]

When measuring ANL in earlier studies above, all followed the procedure described by the original study.[17] In this method, the target speech was recorded by one talker and the background noise was 12-multitalker babble noise. Although a use of the same recorded target speech provides a consistency among studies, there is a possibility that a single target talker may allow the listeners to easily track the target voice against the unintelligible babble noise. Moreover, individual differences in susceptibility to babble noise of 20 voices and reverberation were great for word recognition performance.[18]

Given this, the present study aimed to determine whether ANL values are affected by the gender of target talker (M/F) and the number of background competing talkers (1, 2, 4, 8). First, to evaluate the effect of talker gender, this study recorded a target story from six talkers (3 males, 3 females). By presenting all the six target stories to the listeners, we wanted to examine whether different voice features among male and female talkers would significantly affect ANLs. Second, we also varied the number of competing speech talkers (from 1 to 8) when measuring of ANL to explore whether the meaningful competing speech maskers such as 1- or 2-talker masker give more interferences, allowing less acceptance of noise. Lastly, this is the first attempt to measure ANLs of Korean normal-hearing listeners. Thus, the results of current study would help us establish the ANLs of Korean listeners who have normal hearing as well as compare the ANLs between Korean and American listeners.

MATERIALS AND METHODS

Participants

Twenty adults (9 males, 11 females) served as participants for this study. Both ears of the participants (M= 26 years, SD=2.09, range=23−30) showed hearing thresholds no greater than 15 dB HL within the frequency range from 125 to 8,000 Hz, and all had Type A tympanograms. Puretone audiometry and tympanometry above were conducted using Grason-Stadler GSI 61 and Interacoustics AT235h, respectively. All subjects had no history of tinnitus, neurologic disorder, and speech-language disorder.

Test materials

Recording of target story

Six talkers (3 males, 3 females) who had normal hearing (mean age=27) and were native Korean speakers participated as target talker. All the procedures to record the target story followed the original method.[17] Each talker read stories of an easy history book about five minutes. Different parts were randomly excerpted from the book as a target story because the stories should not be the same each other. As in the original method, the easy history book was for the school-aged children such that stories were all understandable to the adult listeners and stories could represent a typical daily listening environment. A recording of each story was conducted in a double-wall sound booth with a Computerized Speech Laboratory (Kay Elemetrics) speech analyzer and SM48, SHURE microphone. The microphone was situated 30 cm from speakers' lips. Recorded wavefiles were stored using a sampling rate of 44,100 Hz, mono channel, and 16-bit resolution. All the target stories recorded from 6 talkers were controlled to have equalized average RMS (Root Mean Square) values via Adobe Audition 3.0. After this, we analyzed the long-term average speech spectrum (LTASS) of six talkers' stories (using a FFT size of 1,024 and Blackmann-Harris window in Adobe Audition). As plotted in <Fig. 1>, LTASS of each talker was somewhat similar up to 4,000 Hz.

Recording of competing speech maskers

Eight talkers (4 males, 4 females) who did not participate as a target talker participated to record competing speech noise. All the eight participants had normal hearing (mean age=26) and they were native Korean speakers. Participants read newspapers and magazines to record background speech noise in sound booth. A speech wavefile recorded from one male or one female among 8 talkers was randomly chosen as one-male or one-female speech masker. Two-talker speech masker derived from a mixture of another male and female talkers. Four-talker speech masker consisted of wavefiles from 2 male and 2 female talkers. Similarly, eight-talker speech masker constructed from 4 male and 4 female talkers' recordings. In this way, five different competing speech maskers were generated.

To equalize the overall intensity of 5 different speech maskers above, average RMS values of 5 speech maskers were csontrolled to be equal via Adobe audition 3.0. The LTASS of recorded speech noises was also analyzed using the same method above (a FFT size of 1,024 and Blackmann-Harris window in Audobe Audition). <Fig. 2> compares the LTASS of 5 speech maskers [1 (Male), 1 (Female), 2-, 4-, 8-talker speech maskers]. As shown, overall, the LTASS appeared similar.

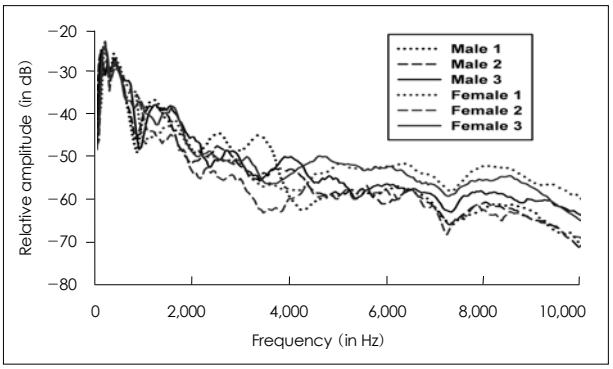

Fig. 1. Long-term average speech spectrum (LTASS) of the six target talkers (Male 1−3, Female 1−3).

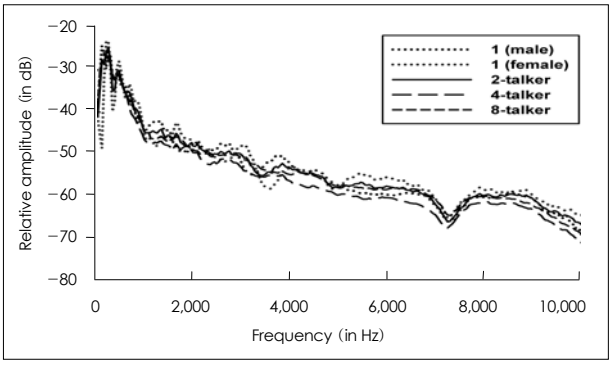

Fig. 2. LTASS of the competing speech maskers [1 (male): 1 male, 1 (female): 1 female, 2-talker: 1 male +1 female, 4-talker: 2 male + 2 female, 8-talker: 4 male + 4 female].

Procedure

ANL measurement was conducted in a sound booth meeting ambient noise requirements.[1] Materials to measure ANL were presented through one loudspeaker located at 0° azimuth nearly 1 meter from the listener, as shown in <Fig. 3>.[16]

To measure ANL, the recorded target story and one of the five speech maskers should be presented together. For the simultaneous presentation, a laptop computer (SENS P55, SAMSUNG) simultaneously delivered two sounds to a calibrated audiometer of GSI 61 (Grason-Stadler).[2] Then, the setting of GSI 61, as displayed in <Table 1>, was used to present the target story and the speech masker together. Each signal of the target story and the speech masker was calibrated through a sound level meter (type 215-0L, Bruel and Kjaer) in order to present each signal at 65 dB SPL. Among 6 talkers' different target stories and 5 types of competing speech maskers [1 (M), 1 (F), 2-, 4-, 8-talker], the target talker and the speech masker were randomly selected, yet each of them was presented once.

For the measurement of ANL, two values should be obtained. First one is the most comfortable level (MCL) to listen to the target story in quiet. Second value is the maximum background noise level (BNL) that listeners could accept while following the target story at MCL. Other than MCL and BNL, uncomfortable level (UCL) was also measured following the original procedure of ANL. The UCL was obtained to identify the dynamic range (Threshold-UCL) of listeners, measured in 5 dB steps. The ANL is then calculated by subtracting the BNL value from the MCL value [ANL=MCL-BNL]. For example, let's say that

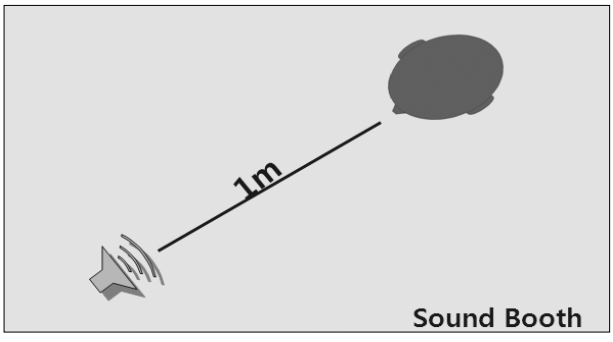

Fig. 3. Experimental setup.

Table 1. Measurement for ANL setting of GSI61 condition

	Channel 1 (Target talker)	Channel 2 (Competing speech masker)
Stimulus	External A	External B
Transducer	Speaker	Speaker
Routing	Left	Left
Intensity	MCL	BNL

a person's MCL was 45 dB HL when listening a target story in quiet. Now the person should listen to the same story in background speech noise. When the person following the target story at 45 dB HL (MCL), the person could allow the noise level of 40 dB HL as maximum, which means that BNL is 40 dB HL. Using the equation [ANL=MCL-BNL], the person's ANL is 5 dB.

Prior to data collection, each participant was given written instruction about two measurements (MCL, BNL). This instruction was in Korean, but was constructed based on the original ANL instruction.[17] To measure both MCL and BNL values, subjects should self-select level-up or level-down signaling by thumb-up or thumb-down, respectively. When the listeners signaled level-up or level-down for the MCL and BNL measurements, 2 dB steps were used to adjust the sound intensity.

Data analysis

Data of the present study were statistically analyzed the using SPSS (statistical program for social science) version 15. Two independent variables were the gender of target talker (3 males, 3 females) and the number of the competing speech maskers [1 (M), 1 (F), 2-, 4-, 8-talker]. Dependent variable was ANL value of each listener (N=20). To examine the effects of the target talker gender and the number of competing talkers, a two-way analysis of variance (ANOVA) with repeated measures was performed. If necessary, additional post-hoc analyses were also conducted.

RESULTS

In the present study, the ANL of 20 normal-hearing adults was evaluated using 6 different target talkers (3 males: M1-M3, 3 females: F1-F3) and 5 different types of speech maskers (with 1 (M), 1 (F), 2-, 4-, 8-talker maskers). Overall results are displayed in <Table 2>. As shown, the ANL ranged from 6.2 to 14 dB. The lowest ANL (6.2 dB) was found when the target talker was male (M1) and the background speech was eight-talker babble. The highest

Table 2. Mean, range, and standard deviations (SD) of the ANLs (in dB) for each of 6 target talkers (M 1−3, F 1−3) and 5 speech maskers (from 1−talker to 8−talker maskers)

6 target talkers (M 1−3, F 1−3)		Number of competing talkers					
		1 (M)	1 (F)	2	4	8	Total
M1	Mean	10.6	10.1	9.4	6.6	6.2	8.6
	Range	4−20	0−22	0−18	−4−16	−4−18	0−17
	SD	4.86	5.45	4.99	4.68	5.94	4.84
M2	Mean	10.9	11.4	9.5	7.8	7.7	9.5
	Range	4−18	6−20	4−18	−2−18	0−18	4−17
	SD	3.46	3.38	3.72	4.44	4.55	3.35
M3	Mean	13.0	12.5	11.1	8.1	8.2	10.6
	Range	4−22	4−20	2−18	0−18	0−20	2−18
	SD	3.92	3.55	3.97	4.83	5.02	3.66
F1	Mean	12.5	11.4	9.9	8.4	8.5	10.1
	Range	4−22	4−20	2−18	−2−16	−2−18	1−18
	SD	4.35	3.90	4.56	4.33	4.58	3.88
F2	Mean	13.7	14.0	11.4	9.9	9.2	11.6
	Range	8−22	8−22	6−24	2−18	0−18	6−20
	SD	4.41	4.40	4.95	4.61	4.96	4.09
F3	Mean	11.6	11.8	8.9	8.0	7.1	9.5
	Range	2−22	4−22	0−14	2−14	0−16	2−17
	SD	5.26	4.54	3.70	3.31	5.00	3.95
M1−M3 avg	Mean	11.5	11.3	10.0	7.5	7.4	9.5
	Range	7−20	5−21	4−18	0−15	0−16	3−17
	SD	3.36	3.63	3.55	4.05	4.77	3.57
F1−F3 avg	Mean	12.6	12.4	10.0	8.8	8.3	10.4
	Range	5−21	7−20	3−17	2−15	1−17	4−17
	SD	3.83	3.31	3.43	3.45	4.26	3.41
Total avg	Mean	12.0	11.9	10.0	8.1	7.8	10.0
	Range	6−21	6−20	4−17	1−15	0−16	3−17
	SD	3.28	3.18	3.15	3.47	4.22	3.22

ANL (14 dB) was obtained when the target talker was female (F2) and the background speech masker was from one female.

Effect of target talker gender on ANL

The ANLs were compared when the target talker was male or female aginst 5 background speech maskers. The averaged ANLs from three male talkers (M1-M3) were 11.5, 11.3, 10, 7.5, 7.4 dB for the 5 different speech maskers, respectively. Also, averaged ANLs from three female talkers (F1-F3) were 12.6, 12.4, 10, 8.8, 8.3 dB for the same 5 different speech maskers. A common trend was that ANL decreased as the number of competing talkers increased, regardless of the target-talker gender. When averaging across 5 speech maskers, ANLs from male talkers and fe-male talkers were 9.5 and 10.4, respectively <Fig. 4>. Results of statistical analyses <Table 3> revealed that the ANL did not differ by the gender of target talker no matter what speech masker was used [$F(1,19)=2.11, p>.05$].

Effect of the number of competing talkers

To measure the effect of the number of competing speech maskers, five different speech maskers were used. As mentioned above, 2-, 4-, 8-talker speech maskers were derived from the same number of male or female talkers. As in <Fig. 5>, the mean ANLs averaged across 6 target talkers were 12.04, 11.86, 10.04, 8.13, 7.82 dB for each of the 5 speech maskers. Statistical results showed that the number of competing talkers constructing the 5 different speech maskers significantly affected the ANL values (Table 3). This indicates that with a greater the number of competing talkers, listeners were relatively less annoyed by unintelligible multitalker noise such that listeners could accept more energy of noise while listening to the target story.

Multiple comparison results using Bonferroni method, as shown in <Table 4>, revealed that there was no significant difference ($p>.05$) between 1-male and 1-female speech masker, indicating that the gender of 1-talker masker did not make a significant effect on ANL. Also, no significant difference ($p>.05$) was found between 4-talker and 8-talker speech maskers. Other than that, all the comparisons showed significant differences ($p<.05$). This confirms that the listeners had a similar amount of annoyance from noise when the speech maskers consisted of 4 or more competing talkers.

DISCUSSIONS AND CONCLUSIONS

Effects of the target talker gender on ANL

In the present data, there was no significant difference in ANL whether the target talker was male or female. This finding was similar with the earlier investigations,[17)19)] supporting no effect of target-talker gender on ANL. However, any characteristics of the target talker may impact spe-

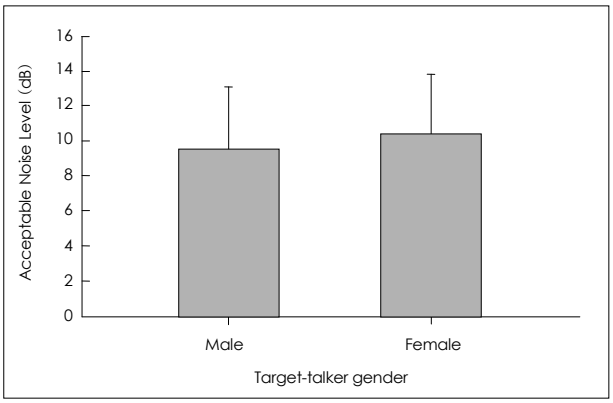

Fig. 4. Mean ANLs depending on target-talker gender, averaged across 5 speech maskers.

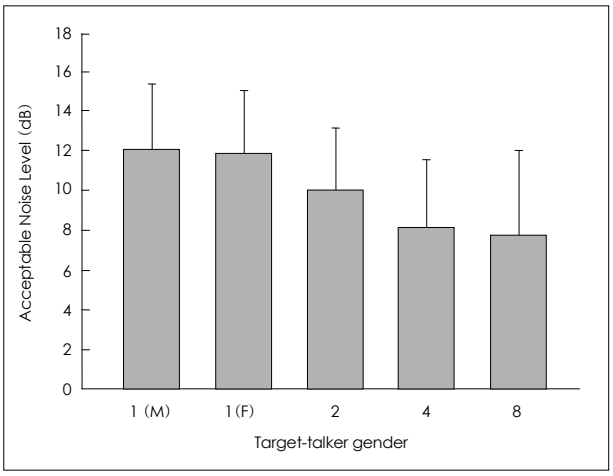

Fig. 5. Mean ANLs depending on competing speech maskers, averaged across 6 target talkers [1 (M): one male masker, 1 (F): one female masker, 2: 2-talker, 4: 4-talker, 8: 8-talker maskers].

Table 3. Results of two-way ANOVA analyses.

	Variables	df	error	F value	*p* value
Main effects	Target talker gender	1	19	2.11	.162
	Number of competing talkers	4	76	35.96	.000*
Interaction	Target talker gender × Number of competing talkers	4	76	2.16	.08

*: $p<.05$

ech recognition scores,[15] and the acoustic features of target talker also seem to affect the speech-understanding of normal-hearing and hearing-impaired listeners.[14] Given this, in the clinical point of view, more research should be continued to evaluate effects of talker variability such as gender or familiarity on ANLs of hearing-impaired listeners.

Effects of background noise variability on ANL

We found that the ANL significantly decreased when the number of competing talkers increased (from 1 to 8) although the average RMS of speech maskers was controlled to be equal. That is, the lowest ANL (more acceptance of noise) was obtained from 8-talker masker while the higher ANL (less acceptance of noise) was obtained from 1-talker speech masker. The reason on this would be that 4- or 8-talker speech masker has the acoustic characteristics of speech sounds yet does not provide meaningful interference as a masker, like speech-spectrum noise. Therefore, the babble noise was less annoyant and the listeners actually accepted more noise while listening to the target story. On the other hand, the meaning of 1-talker masker can be highly intelligible, producing more annoyant and confusable listening situation. Since noise annoyance from background speech depends on audibility (energetic masking) as well as meaningfulness of background speech (informational masking), the choice of the background speech noise should be carefully determined for the clinical purpose.

A significant effect of the number of competing talkers has been also observed in speech recognition tests. Speech-reception threshold (SRT) significantly differed between 1- and 2-talker maskers.[5] Consonant identification performance was also significantly different from 1-talker to 8-talker, yet similar from 8- to 128-talker maskers due to unintelligible meaning.[20]

Several previous studies attempted to compare ANLs using various kinds of background noise, as summarized in <Table 5>. When the ANLs of normal-hearing listeners were compared using 5 different background noises (speech-babble noise, speech-spectrum noise, traffic noise, drill noise, and music), the ANL did not significantly differ by the background noise except music.[17] However, the ANLs significantly differed when the background noise was speech-babble or speech-spectrum noise.[8] Also, a significant difference in ANL was found between speech-babble and music noise.[10] Unlike the higher ANL with back-

Table 4. Multiple comparison results based on Bonferroni method among 5 different speech maskers [1 (M): one male masker, 1 (F): one female masker, 2: 2-talker, 4: 4-talker, 8: 8-talker maskers]

	1 (M)	1 (F)	2	4	8
1 (M)		–	–	–	–
1 (F)			–	–	–
2	*	*		–	–
4	*	*	*		–
8	*	*	*		

*: $p<.05$

Table 5. ANLs with various background noises in earlier investigations

	Nabelek et al. (1991)[17]	Freyaldenhoven et al. (2006)[8]	Gordon-Hickey et al. (2007)[10]
Speech-babble noise	12.35	12.9	9.92
Speech-spectrum noise	13.03	15.0	–
Traffic noise	10.92	–	–
Drill noise	11.83	–	–
Music	15.47	–	6.25

Table 6. Comparison of ANL values between present and previous studies

Study	Language	Background noise		MCL	BNL	ANLs (dB)
Present study N=20	Korean	8-talker babble noise	Mean	34.3 dB HL	26.5 dB HL	7.8
			Range			0-16
Nabelek et al. (1991)[17] n=14	English	12-talker babble noise	Mean	63.8 dB SPL	47.9 dB SPL	15.9
			Range			5-37
Rogers et al. (2003)[19] n=50			Mean	39.2 dB HL	28.3 dB HL	10.9
			Range			0-24.7
Freyaldenhoven et al. (2006)[8] n=30			Mean	–	–	12.9
			Range			4-24
Franklin et al. (2006)[6] n=20			Mean	42.7 dB HL	27.2 dB HL	15.5
			Range			–

ground music,[17] the ANL value was found to be lower in the background music.[10] Considering those contradictory findings, more studies are needed to determine ANLs with a control of variability in various background noises.

Comparisons of ANLs among korean and american normal-hearing listeners

The current study measured ANLs of 20 Korean normal-hearing adults. The ANL value of Korean lilsteners was compared with the mean ANLs of American listeners based on four earlier studies. The details on comparison are reported in <Table 6>.

As shown, the mean ANL of 20 Korean listeners was 7.8 dB (range=0−16 dB) when 8-talker masker was used as a background noise. From the four previous studies, the ANLs of American listeners ranged from 10.9 to 15.9 dB. Thus, the ANL of Korean listeners seems little lower than that of American listeners although the range of ANLs overlapped each other. Although we used 8-talker babble and the data from American listeners used 12-talker babble, it is speculated that the 8-talker and 12-talker babble maskers may be similarly unintelligible, giving no great difference. Possible reasons on this difference could be individual differences in the noise annoyance, any difference of test environment, and the issue of cultural difference. Given the large individual differences among earlier ANL studies, more data of young normal-hearing adults as well as hearing impaired listeners should be collected. Since the ANLs of hearing-impaired listeners were related to their successful use of hearing aids,[9] the ANL data of Korean hearing-impaired listeners would be very useful to consult Korean hearing-impaired listeners who especially feel annoying in noise.

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