

## Measurement of Acceptable Noise Level with Background Music

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**Background and Objectives:** Acceptable noise level (ANL) is a measure of the maximum background noise level (BNL) that a person is willing to tolerate while following a target story. Although researchers have used various sources of target sound in ANL measures, a limited type of background noise has been used. Extending the previous study of Gordon-Hickey & Moore (2007), the current study determined the effect of music genre and tempo on ANLs as possible factors affecting ANLs. We also investigated the relationships between individual ANLs and the familiarity of music samples and between music ANLs and subjective preference. **Subjects and Methods:** Forty-one participants were separated into two groups according to their ANLs, 29 low-ANL listeners and 12 high-ANL listeners. Using Korean ANL material, the individual ANLs were measured based on the listeners' most comfortable listening level and BNL. The ANLs were measured in six conditions, with different music tempo (fast, slow) and genre (K-pop, pop, classical) in a counterbalanced order. **Results:** Overall, ANLs did not differ by the tempo of background music, but music genre significantly affected individual ANLs. We observed relatively higher ANLs with K-pop music and relatively lower ANLs with classical music. This tendency was similar in both low-ANL and high-ANL groups. However, the subjective ratings of music familiarity and preference affected ANLs differently for low-ANL and high-ANL groups. In contrast to the low-ANL listeners, the ANLs of the high-ANL listeners were significantly affected by music familiarity and preference. **Conclusions:** The genre of background music affected ANLs obtained using background music. The degree of music familiarity and preference appears to be associated with individual susceptibility to background music only for listeners who are greatly annoyed by background noise (high-ANL listeners).

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**KEY WORDS:** Acceptable noise level · Background music · Familiarity · Preference.

### Introduction

Background noise is pervasive in a wide range of our everyday environments including home, workplace, school, transportation, store, and recreational spaces. Under noisy environments, some people may experience difficulties understanding speech in noise whereas some may have less problems. Considering the large variability in individual susceptibility to

noise, Nabelek, et al. [1] quantified the lowest signal to noise ratio that a person could accept while listening to speech. This noise level that an individual can tolerate or accept is called acceptable noise level (ANL). The ANL test appears to be a quick, reliable, clinician-friendly procedure [2]. Unlike speech-in-noise recognition test, listener does not need to repeat the target speech they heard for ANL measurement. Rather, the ANL is calculated by difference between the most comfortable level for speech and the maximum level of background noise that the listener is willing to accept while following the target story.

Although various types of sound sources have been used as target sound such as reversed, unfamiliar discourses, and non-

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semantic sound sources [3-5], little research has focused the individual susceptibility to interference from background music [6-8]. To our knowledge, only a few studies [1,6] have reported ANLs to background music using different genres of music. In the previous study of Nabelek, et al. [1], 'light music' of waiting room was first used as source of background noise to examine listeners' ANLs to music. In Gordon-Hickey and Moore [6], music of rock genre was only used as background noise for ANL measurement. Comparing the results of young normal-hearing adults between two studies, Nabelek and colleagues [1] reported that 'light music' was more demanding compared to multi-talker babble noise whereas Gordon-Hickey and Moore [6] found more acceptance of rock-genre music than babble noise. For the inconsistent finding, the authors speculated a substantial impact of musical attributes such as music tempo, genre, familiarity, and musical experience.

Since no studies have examined the influence of music tempo and genre on ANLs, the present study aimed to determine whether music tempo and genre would affect individual ANLs. In addition, this study investigated whether music familiarity and preference would influence the ANLs. To facilitate comparison with the previous finding of Gordon-Hickey and Moore [6], this study grouped participants into low-ANL group (listeners with greater acceptance of noise) and high-ANL group (listeners with lower acceptance of noise). This would allow us to investigate whether music preference or familiarity would affect ANLs differently between low-ANL and high-ANL groups.

## Subjects and Methods

### Participants

A total of forty-one (21 males, 20 females) native Korean listeners participated in this study. According to the previous criteria [6,9], the participants consisted of 29 low-ANL listeners ( $\leq 6$  dB) and 12 high-ANL listeners ( $\geq 14$  dB). All the participants had Type-A tympanogram with no history of neurologic pathology. The mean age of low-ANL group ( $n=29$ ) was 47.2 years of age [standard deviation (SD): 23.4], and the mean age of high-ANL group ( $n=12$ ) was 47.1 years of age (SD: 17.0). The mean puretone threshold of two groups was less than 20 dB HL from 250 to 2000 Hz, and less than 30 dB HL at 4000 and 6000 Hz. Analyses of independent t-test showed that the ages and the octave-scale puretone thresholds from 250 to 6000 Hz did not significantly differ ( $p>0.05$  for all frequencies) between low-ANL and high-ANL groups. Additional analyses of Pearson correlation verified no significant relations between ANLs and puretone threshold average and also between ANLs and ages of individuals, consistent with

previous finding [1]. Before the experimental test, participants were informed of anticipated risk and benefit and all were agreed to participation in research before the experimental testing.

### Stimuli and procedure

For the ANL measure, a recorded discourse of a male talker in Korean [10] was used as target story. As background noise, ANLs were tested in six different music categories consisting of three music genres (Korean-pop music: K-pop, popular music: pop, and classical music: classical) and two types of music tempo (fast and slow). Each of the six categories included three music samples, resulting in 18 music samples as total, as displayed in Table 1. Selecting as either fast or slow tempo was based on two aspects as follows. First, as an objective standard, the number of beats per minute (BPM) was considered, as in the previous criteria [11]. Thus, 94 or more BPM was required to be fast tempo music whereas 72 or less BPM for the slow tempo music. Especially for the classical music, the tempo was based on the Quarter-notes Per Minute (QPM) such that Adagio (60–80 QPM) classical music was chosen as slow classical music and Allegro (120–160 QPM) was selected as fast classical music. Second, as described in the previous studies which measured ANLs to background music [1,6], a single instrumental part was avoided such that vocal parts with lyrics were selected as music samples of K-pop and pop genres. In contrast, the instrumental part without lyrics was selected as music sample of classical genre. All the wavefiles were downloaded from K-pop archive charts. The average root mean square value of each wavefile was equated via Adobe Audition version 3.0 (Adobe Systems Incorporated, San Jose, CA, USA) with 16-bit resolution and a sampling rate of 44.1 kHz. The order for the presentation of background music was randomly selected for each participant.

All the stimuli were delivered via clinical audiometer (Madsen Obiter 922, GN Otometrics, Taastrup, Denmark) connected to an external CD player (DEJ017, Sony, Tokyo, Japan) and a loudspeaker at 0 degrees azimuth to the subject. Prior to the experimental test, a practice with verbal and written instructions in Korean [10] was given to ensure whether the participant understood task correctly. Subjects' ANLs were obtained based on the procedure of the previous study [1] which first introduced ANL. For the ANL measure, each participant was required to adjust level of a target story in 2 dB steps to find individual's most comfortable level (MCL). While listening to and following the target message at MCL, the listener was then required to adjust level of background music in 2 dB steps to find the maximum level that the listener was willing to accept, called background noise level (BNL). The ANL

**Table 1.** Music samples used as background noise

Genre	Tempo	Title of music	Artist	Year
K-pop	Slow	Happy me	Eco	1997
	Slow	I know only love	Subong Sim	1987
	Slow	You'll never know	Euni Hye	1975
	Fast	Festival	Junghwa Uhm	1999
	Fast	Round and round	Na-Mi	1984
	Fast	Like Indian Doll	Na-Mi	1990
Pop	Slow	Like a star	Corinne Bailey Rae	2006
	Slow	When I dream	Crystal Gayle	1978
	Slow	The rose	Bette Midler	1979
	Fast	Single ladies	Beyonce	2011
	Fast	Sunny	Boney M	1976
	Fast	Conga	Glpria Estefan	1985
Classical	Slow	Sonata for Flute and Basso Continuo No. 2 in E minor BWV 1034	Johann Sebastian Bach	1720
	Slow	Flute Concerto in G major, K.313/285c	Mozart, Wolfgang Amadeus	1777
	Slow	Air on a G String	Johann Sebastian Bach	1717
	Fast	Beethoven symphonie Nr.9. Adagio molto e cantabile	Ludwig van Beethoven	1824
	Fast	Four seasons, Summer	Antonio Vivaldi	1725
	Fast	L'estro armonico	Antonio Vivaldi	1711

K-pop: Korean-pop music, Pop: popular music, Classical: classical music

**Table 2.** Mean ANL values (standard deviations) of low-ANL and high-ANL groups depending on music tempo and genre

	Slow music			Fast music			K-pop mean	Pop mean	Classical mean	Total means
	K-pop	Pop	Classical	K-pop	Pop	Classical				
Low-ANL group	2.5 (2.0)	2.2 (2.2)	2.3 (2.4)	4.1 (2.3)	3.0 (1.9)	3.1 (2.4)	3.3 (2.0)	2.6 (1.9)	2.7 (2.2)	2.9 (1.8)
High-ANL group	17.8 (4.3)	17.4 (5.3)	17.3 (6.1)	17.5 (2.2)	16.1 (2.8)	16.1 (3.1)	17.6 (3.1)	17.0 (3.7)	16.0 (4.3)	17.0 (3.5)
Group mean	7.0 (7.6)	6.6 (7.8)	6.7 (7.9)	8.0 (6.5)	6.8 (6.5)	6.9 (6.5)	7.5 (7.0)	6.8 (7.1)	6.6 (6.8)	7.0 (7.0)

ANL: acceptable noise level

was determined by subtracting BNL from MCL (ANL=MCL-BNL). After the ANL test, participants were asked to judge the degree of familiarity and preference on each music sample using a 4-point scales, as used in the previous study on music familiarity [12]. On this questionnaire, the greater numbers correspond to the higher levels of familiarity or preference. To complete all the task, approximately 90 minutes were needed.

### Analysis

All the statistical analyses were performed using SPSS version 20.0 (IBM Corp., Armonk, NY, USA). First, a 2 (group) × 2 (tempo) × 3 (genre) three-way mixed-model analysis of variance (ANOVA) was conducted on ANLs as dependent variable. Group was a between-subjects variable (low-ANL and high-ANL), and music tempo (fast and slow) and music genre (K-pop, pop, and classical) were used as two within-subjects variables. Second, in order to examine any relationship of ANLs with subjective responses, non-parametric analyses of Spearman's rank-order correlation were conducted on

music preference and music familiarity for low-ANL and high-ANL groups, separately. For analyses with a lack of sphericity, the degrees of freedom and F values were adjusted with the Greenhouse-Geisser correction. If necessary, any post-hoc multiple comparisons were conducted. The critical level of significance was always  $p < 0.01$  in this study.

## Results

### Effect of music tempo and genre on ANLs for low-ANL and high-ANL groups

Table 2 shows the mean ANL and standard deviation for low-ANL and high-ANL groups when background music differed by music tempo and genre. When the background music of slow tempo was presented, the mean ANLs ranged from 2.2 to 2.5 dB for low-ANL listeners and ranged from 17.3 to 17.8 dB for high-ANL listeners across three music genres. When the fast-tempo music was presented, the mean ANLs of low-ANL group were 4.1, 3.0, and 3.1 dB and the mean ANLs of

high-ANL group were 17.5, 16.1, and 16.1 dB for K-pop, pop, and classical music, respectively.

A 2×2×3 three-way mixed-model ANOVA was performed on ANLs and the results showed that the main effect of group was significant [ $F(1, 39)=281.5$ ]. Also, we found that music genre significantly influenced the ANLs [ $F(1.73, 67.64)=5.36$ ] but music tempo did not significantly influence the ANLs. Results from Bonferroni-adjusted multiple paired-comparisons revealed that the ANLs to K-pop music were significantly greater than the ANLs to pop or classical music. A two-way interaction between tempo and group was significant [ $F(1, 39)=9.78$ ], showing higher ANLs with fast music for low-ANL group yet in opposite for high-ANL groups. Other two-way interactions as well as a three-way interaction among tempo, genre, and group were not significant. This indicates that the K-pop music which includes vocal part with Korean lyrics yields the greatest amount of interference as background noise.

#### Relationship between ANLs and subjective responses (music familiarity and music preference)

This study investigated individual music familiarity and preference on each music sample in order to examine whether the ANLs would be related to individual's familiarity and preference. The mean values of music familiarity was 2.5 (SD: 0.6) and 2.4 (SD: 0.8) for low-ANL and high-ANL groups, respectively. The mean values of music preference was 2.3 (SD: 0.5) and 2.1 (SD: 0.7) for low-ANL and high-ANL groups, respectively.

The independent t-test showed that the subjective responses did not statistically differ between low-ANL and high-ANL groups on both music familiarity [ $t(39)=0.37$ ] and preference [ $t(39)=1.01$ ].

Non-parametric analyses of Spearman's rank-order correlation were administered to determine any association between individual noise acceptance and their subjective preference or familiarity to music samples. In order to investigate this, we examined relationship between individual ANLs and subjective responses for low-ANL and high-ANL groups. Table 3 shows the Spearman's coefficients rho for low-ANL and high-ANL groups. As displayed, for low-ANL individuals, their acceptance of background music was relatively unaffected by music familiarity and preference, regardless of music genre. However, the results on correlated measures revealed a different tendency in high-ANL group. For high-ANL individuals, the ANLs were significantly and negatively related to subjective ratings of music familiarity and preference when the music samples were from K-pop ( $-0.83 < r_s < -0.73$ ) or pop genre ( $-0.87 < r_s < -0.75$ ). That is, the subjective preference or familiarity of background noise would affect noise acceptance only for the high-ANL listeners, rather than for all listeners.

**Table 3.** Spearman's rank-order correlation coefficients rho values between ANLs and subjective familiarity and preference responses across three music genres (K-pop, pop, and classical) for low-ANL and high-ANL groups

Correlated measures	Correlation coefficient rho ( $r_s$ )	Significance level ( $p$ )
Low-ANL group		
ANL and familiarity with K-pop	-0.07	$p > 0.01$ for low-ANL group
ANL and familiarity with pop	-0.41	
ANL and familiarity with classical	-0.36	
ANL and preference with K-pop	0.21	
ANL and preference with pop	-0.50	
ANL and preference with classical	-0.27	
High-ANL group		
ANL and familiarity with K-pop	-0.73	$p < 0.01$
ANL and familiarity with pop	-0.75	$p < 0.01$
ANL and familiarity with classical	-0.54	$p > 0.01$
ANL and preference with K-pop	-0.83	$p < 0.01$
ANL and preference with pop	-0.87	$p < 0.01$
ANL and preference with classical	-0.48	$p > 0.01$

ANL: acceptable noise level

## Discussion

Although various types of target stories and listening conditions have been used for ANL measure [3-5,10,13], a source of background sound has been limited other than use of multi-talker babble noise. Despite a widespread and common use of music in everyday life, little research has explored the effect of music as background noise on ANLs [1,6]. Gordon-Hickey and Moore [6] who used one genre of rock as music samples suggested a need of more research to explore individual susceptibility to background music with controlling musical attributes such as tempo, genre, and instrument composition. This has driven this study to investigate the effect of music tempo and genre on individual ANLs to music.

Results of this study showed that K-pop music was relatively less accepted as background noise, resulting in a relatively greater amount of noise distraction (higher ANL) compared to pop or classical music. Interestingly, the significant effect of genre on ANLs was similar in both low-ANL and high-ANL groups. As one of the possible reasons, the native Korean participants could have been greatly annoyed by K-pop music due to meaningful content of K-pop songs. This seems consistent with previous ANL measures which compared ANLs across five types of competing speech maskers (e.g., 1-male, 1-female, 2-talker, 4-talker, and 8-talker speech masker) [10,14,15]. Considering the features of relatively reduced temporal fluctuations and unintelligible meaning in babble noise as background, researchers have examined individuals' noise acceptance as a

function of the number of the competing talkers. The findings were congruent such that acceptance of background noise was significantly poorer (or higher ANL) when the background speech masker became more meaningful (i.e., 1- or 2-talker noise) for young normal-hearing listeners [10], adult hearing aid users [14], and adults who use cochlear implant [15]. This indicates that annoyance from background noise may depend on informational masking of noise. Thus, selecting a type of the noise source should be carefully considered for clinical measures of ANLs and also when comparing data across ANL studies who used different materials.

Although it was not the primary interest of this study, no relation was found between ANLs and individuals' age or hearing threshold, consistent with previous findings [1,2,16,17]. This supports the previous findings that ANL might be an inherent characteristic of individual, which is unchangeable with age or acquired hearing loss of listeners. Recent research revealed that the ANLs could be based on subjective loudness [18], self-control level [19], and personality [20]. Considering the substantial impact of subjective and inherent characteristics of the individuals on their ANLs, it seems important to investigate whether the greater annoyance from K-pop music would be associated with self-rating responses on music familiarity and preference.

To clear this out, the present study explored any association between ANLs and individual familiarity or preference to music samples. The results revealed a different tendency on correlated measures between listeners with low-ANL ( $n=29$ ) and high-ANL ( $n=12$ ). Results showed that the ANLs of low-ANL group were independent of their subjective responses of music familiarity and preference. This seems similar with previous finding [2] who reported no significant correlation between ANLs and individual preference to background noise. Gordon-Hickey and Moore [6] also showed no association between ANLs and participants' music preference. However, we found that the ANLs of high-ANL group depended on music familiarity and preference. Expected result to observe was that the listeners would accept more noise (lower ANL) with less familiar and less preferred background music, meaning a positive association between ANLs and subjective responses (music familiarity and preference). Unexpectedly, negative correlations were observed between ANLs and subjective responses of high-ANL group (less acceptance of background music for less familiar or less preferred music). Possibly, the relatively less familiar or less preferred music could introduce new conflicting cues, resulting in more distraction when following a target story. If a listener had a good strategy to suppress familiar music entirely, then the familiarity of music would be beneficial, as reported using word identification [12]. However, a

limitation of the study is the relatively small sample size especially for high-ANL group ( $n=12$ ) such that more research is needed to determine whether subjective familiarity or preference on noise can affect a person's capacity to accept background noise.

## Conclusion

The purpose of the current study was to evaluate the effects of music genre and tempo on the ANLs to background music. Results showed that, overall, the ANLs did not significantly differ by music tempo. The ANLs depended on the genre of background music. Since K-pop music with more meaningful lyrics was poorly accepted than pop or classical music for both low-ANL and high-ANL groups, the degree of informational masking would decrease acceptance of background noise. The subjective familiarity and preference of noise had a great impact on ANLs only for high-ANL group.

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